MEMORANDUM

SUBJECT: Request for Concurrence on the Decision Document/Explanation of Significant Differences for the NL Industries/Taracorp Site in Granite City, Illinois

FROM: William Muno, Director
Waste Management Division
Bertram C. Frey
~~Gail Ginsberg~~, Regional Counsel
Office of Regional Counsel
Atenfr

TO: Valdas V. Adamkus
Regional Administrator

By this memorandum we are recommending that you authorize the retention of the 500 parts per million cleanup level for lead in residential soils and capping of the Taracorp pile, and the changes in the remedial action with respect to the ground water and the remote fill areas at the NL Industries/Taracorp site by executing the attached Decision Document(DD)/Explanation of Significant Differences (ESD).

This DD/ESD was prepared in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act, 42 U.S.C. 9601 et seq., the National Contingency Plan (40 CFR Part 300), and Agency Policy. We have reviewed the attached documents and have concluded that the DD/ESD is both legally and technically sufficient. As such, we believe that the implementation of the remedial measures is a proper exercise of your delegated authority.

Please feel free to contact either one of us should you have any questions.

Concur

Robert Springer
for Valdas V. Adamkus
Regional Administrator

9/29/95
Date

Not Concur

Valdas V. Adamkus
Regional Administrator

Date

DECISION DOCUMENT/
EXPLANATION OF SIGNIFICANT DIFFERENCES
FOR THE
NL INDUSTRIES/TARACORP SITE
GRANITE CITY, ILLINOIS

INTRODUCTION

The purpose of this document is to provide a brief background for the NL Industries Site (NL Site or the Site), and explain which remedial activities will remain the same and which will differ from the Remedial Action (RA) selected by the United States Environmental Protection Agency (U.S. EPA) in the Record of Decision (ROD) signed on March 30, 1990.

The U.S. EPA is issuing this Decision Document to reaffirm its decision regarding the residential soil cleanup level and capping of the Taracorp pile. Because U.S. EPA has determined that there will be no change to the residential soil cleanup level and capping of the Taracorp pile in the March 1990 ROD, the U.S. EPA is not issuing a ROD amendment or an ESD for these portions of the remedy as described in the March 1990 ROD.

The U.S. EPA is issuing an ESD, in accordance with Section 117(c) of the Comprehensive Environmental Response, Compensation, and Liability Act, as amended (CERCLA), and consistent with Section 300.435(c)(2)(i) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), because the changes to the ground water and remote fill portions of remedy as described in the March 1990 ROD constitute a significant change to the remedy.

This presents U.S. EPA's Decision Document (DD)/Explanation of Significant Difference (ESD) for the Remedial Action at the NL Site. This document combines the results of U.S. EPA's re-analysis of the 500 parts per million residential soil lead cleanup level conducted pursuant to an in court agreed public comment period which occurred from October 14, 1994 through January 13, 1995, with U.S. EPA's re-analysis of the remedy for the Taracorp pile and associated ground water contamination and additional remote fill areas pursuant to a second public comment period which occurred from February 17, 1995 through April 19, 1995.

This DD/ESD and corresponding documents will become part of the NL Site's administrative record file and are available for public review. The administrative record is available at the following locations:

Granite City Public Library
2001 Delmar Avenue
Granite City, Illinois 62040

U.S. Environmental Protection Agency
Region V Records Center
77 W. Jackson Blvd. (7HJ)
Chicago, Illinois 60604

phone: (312) 886-0900

The administrative record index for this DD/ESD is included as Attachment 1.

SUMMARY OF SITE HISTORY, CONTAMINATION, AND SELECTED REMEDY

The NL Site, located in Granite City, Madison (including Eagle Park Acres), and Venice, Illinois, is the location of a former secondary lead smelting facility. Metal refining, fabricating, and associated activities have been conducted at the Site since the turn of the century. From 1903 to 1983, secondary lead smelting occurred on-site. Secondary lead smelting operations were discontinued during 1983 and the equipment dismantled. Taracorp Industries, the current owner of the main industrial site, purchased the property from NL Industries, Inc., in 1979.

In July of 1981, St. Louis Lead Recyclers, Inc. (SLLR) began using equipment on adjacent property owned by Trust 454 to separate components of the Taracorp pile. SLLR attempted to recycle lead-bearing materials to the furnaces at Taracorp and send hard rubber and plastic off-site for recycling. SLLR continued operations until March 1983 when it shut down its equipment. Residual lead-bearing waste materials from the operation remain on Trust 454 property, as does some equipment.

A State Implementation Plan for Granite City was published in September 1983 by the Illinois Environmental Protection Agency (IEPA). The IEPA's Report indicated that the nonattainment status for lead air emissions in Granite City was in large part attributable to emissions associated with the operation of the secondary lead smelter operated by Taracorp and lead reclamation activities conducted by SLLR. The IEPA negotiated Administrative Orders by Consent with Taracorp, St. Louis Lead Recyclers Inc., Stackorp, Inc., Tri-City Truck Plaza, Inc., and Trust 454 during March 1984. The Orders required the implementation of remedial activities relative to the air quality. Taracorp subsequently closed its smelting operations.

The NL Site was listed on the National Priorities List, 40 C.F.R. Part 300 (NPL), on June 10, 1986. NL, as former owner of the Site, voluntarily entered into an Agreement and Administrative Order by Consent with the U.S. EPA and IEPA in May 1985 to implement a Remedial Investigation and Feasibility Study (RI/FS). The RI/FS was completed in January 1990.

The RI for the NL Site indicated the need to prevent direct contact with and inhalation of lead-contaminated soils and waste materials in the Taracorp pile, the SLLR piles, and the main industrial site; residential soils contaminated by lead fallout from the smelter stack; and battery case material used as fill material for alleys, driveways, and other areas. Additionally, the RI indicated a need for further ground water monitoring in the deeper zone of the upper aquifer and a mechanism for remediation of any contaminants in the ground water that are detected in concentrations that would present an endangerment to public health and the environment.

Different alternatives to address Site contamination were evaluated in the NL Feasibility Study and Addendum, and after detailed analysis of the alternatives, a Proposed Plan was issued. After taking into consideration all public comments, the Regional Administrator signed a Record of Decision ("ROD") on March 30, 1990. The cleanup decision is embodied in the ROD. The remedy specified therein consisted of the following components:

- o Installation of an upgraded security fence around the expanded Taracorp pile.
- o Deed Restrictions and other institutional controls to prevent access to the Taracorp pile.
- o Performance of soil lead sampling to determine which areas must be excavated and the extent of the excavation.
- o Inspection of alleys and driveways and areas containing surficial battery case material in Venice, Eagle Park Acres, Granite City, Madison and any other nearby communities to determine whether additional areas not identified in the Feasibility Study must be remediated as described below.
- o Performance of blood lead sampling to provide the community with current data on potential acute health effects associated with Site contamination.
- o Installation of a minimum of one upgradient and three downgradient deep wells, monitoring of ground water and air, and inspection and maintenance of the cap.
- o Removal and recovery of all drums on the Taracorp pile at a secondary lead smelter.
- o Consolidation of waste contained in adjacent St. Louis Lead Recyclers piles with the Taracorp pile.
- o Excavation and consolidation with the Taracorp pile or off-Site disposal of battery case material from all applicable alleys and driveways in Granite City, Madison, and Venice, Illinois, and any other nearby communities.

- Excavation and consolidation with the Taracorp pile of all unpaved portions of the adjacent Trust 454, Rich Oil, and BV&G Transport properties with lead concentrations greater than 1000 ppm.

- Excavation and consolidation with the Taracorp pile or off-Site disposal of all residential soils and battery case materials in Granite City, Madison, and Venice, Illinois, and any other nearby communities with lead concentrations greater than 500 ppm.

- Inspection of the interiors of homes on property to be excavated to identify possible additional sources of lead exposure and recommend appropriate actions to minimize exposure.

- Implementation of dust control measures during all remedial construction activities.

- Construction of a RCRA-compliant, multi-media cap over the expanded Taracorp pile and a clay liner under all newly-created portions of the expanded Taracorp pile.

- Development of contingency plans to provide remedial action in the event that the concentration of contaminants in ground water or air (lead or PM_{10} (particulate matter greater than 10 microns)) exceed applicable standards or established action levels, or that waste materials or soils have become releasable to the air in the future.

- Development of contingency measures to provide for sampling and removal of any soils within the zone of contamination described by the soil lead sampling to be implemented above with lead concentrations above 500 ppm which are presently capped by asphalt or other barriers but become exposed in the future due to land use changes or deterioration of the existing use.

Following unsuccessful efforts to negotiate a settlement with the Potentially Responsible Parties (PRPs) for remedy implementation, U.S. EPA, on November 27, 1990, issued an administrative order, pursuant to Section 106 of CERCLA, 42 U.S.C. § 9606, directing certain PRPs to undertake the response actions identified in the ROD. In issuing this Order, U.S. EPA made a number of findings based on the administrative record for the Order before it, including a finding that the release and threat of release of hazardous substances from the facilities at the NL Site is or may be presenting an imminent and substantial endangerment to the public health or welfare or the environment.

None of the recipients of the Order notified U.S. EPA of its intention to comply fully with the Order. In view of the failure or refusal of PRPs to comply with the November 27, 1990, Administrative Order, U.S. EPA decided to use Superfund money to proceed with implementation of the remedy selected in the ROD.

The U.S. EPA has brought an action in Federal Court to compel certain PRPs to perform the Site remedy and to collect penalties for their failure to comply with the 1990 Administrative Order.

U.S. EPA has commenced the Remedial Design (RD) for the NL Site and has conducted early actions to remediate the contaminated residential soil, beginning with the areas of greatest contamination first, and the highly lead-contaminated battery case material that was used as fill material.

Two revised decision documents termed "Explanation of Significant Differences" (ESDs) have preceded this Decision Document and Explanation of Significant Differences (DD/ESD). The first ESD, signed on May 7, 1993, allowed for battery case material that was contaminated with greater than 500 ppm lead but was not hazardous per the Toxic Characteristic Leaching Procedure (TCLP) test found at 40 CFR 261 Appendix II-Method 1311, to be disposed of at an off-site landfill rather than consolidated with the Taracorp pile, as originally specified in the 1990 ROD. The second ESD, signed on January 27, 1994, allowed for disposal of residential soils contaminated with greater than 500 ppm lead and that are not hazardous per the TCLP test at an off-site landfill rather than consolidated with the Taracorp pile, as originally specified in the 1990 ROD.

As a result of an action brought by certain PRPs and the City of Granite City to enjoin U.S. EPA from conducting the remedy, U.S. EPA agreed to reopen the public comment period for the residential soil cleanup level to allow for U.S. EPA's evaluation of all information that has become available subsequent to the March 30, 1990 ROD. Accordingly, U.S. EPA released a Proposed Plan and reopened the public comment period for the residential soil lead cleanup level on October 14, 1994. The proposed plan reaffirmed the 500 ppm residential lead soil cleanup level. Public meetings were held on this matter on October 25 and 26, 1994. The Responsiveness Summary addressing comments received during this comment period comprises Attachment 2 to this DD/ESD. Additional provisions contained in the Proposed Plan that were not in the 1990 ROD were to make a High Efficiency Particulate Arrester (HEPA) vacuum available to residents in the cleanup zone for interior house dust cleaning, and to remediate a truck lot at 1420 State Street to prevent possible lead recontamination of nearby residential properties.

During U.S. EPA's remediation of battery case material, which commenced in the spring of 1993, numerous additional battery case locations were discovered. It is currently estimated that over 100 such locations exist with lead concentrations exceeding 500 ppm. Given this tremendous increase (1990 ROD cost estimates were based on 18 locations) in volume of battery case material to be remediated, U.S. EPA decided to reevaluate the excavation and disposal remedy for the battery case material contained in the 1990 ROD and the subsequent 1993 ESD. The Proposed Plan for the battery case material was combined with that for the Taracorp pile and associated ground water contamination, which is discussed below.

Starting in mid-1992, U.S. EPA changed its sampling protocols for groundwater collection from the monitoring wells on the main industrial area based upon current sampling protocols. The new protocols better characterize ground water contamination.

The results of this sampling and subsequent sampling indicate that ground water downgradient from the waste pile contains among other things, lead levels that greatly exceeded the federal and state drinking water standards.

As a result, U.S. EPA reevaluated the remedy for the Taracorp pile, selected in the 1990 ROD. U.S. EPA also evaluated alternatives for remediation of the contaminated ground water. After conducting some additional studies in late 1994 regarding the treatability of the Taracorp pile and the likely success of some dust suppression techniques during excavation/grading of the pile, U.S. EPA released a Proposed Plan for the Taracorp pile, the ground water, and the additional remote fill areas on February 17, 1995. A public meeting on this matter was held on March 6, 1995. The Responsiveness Summary addressing comments received during this comment period comprises Attachment 3 to this DD/ESD.

In the February 17, 1995 Proposed Plan, the following 5 alternatives were evaluated for addressing the Taracorp pile and contaminated solid materials at the Main Industrial Area:

1) Alternative M-A: Capping of the Taracorp Pile per the 1990 ROD;
2) Alternative M-B: Source Removal to On-Site Landfill and On-Site Treatment of Material Characterized as Hazardous Waste;
3) Alternative M-C1: Source Removal to Off-Site Landfill and Off-Site Treatment of Hazardous Waste;
4) Alternative M-C2: Source Removal to Off-Site Landfill and On-Site Treatment of Hazardous Waste; and
5) Alternative M-D: Source Removal with On-Site Sorting and Treatment, Off-Site Recycling, and On- or Off-Site Disposal.

U.S. EPA has chosen to retain the capping remedy (Alternative M-A) outlined in the 1990 ROD. The bases for this decision are outlined below.

In the February 17, 1995 Proposed Plan, the following 2 alternatives were evaluated for addressing the remaining Remote Fill Areas:

1) Alternative RF-A: Removing Remote Fill from Residential Areas, Treating Remote Fill Characterized as Hazardous, and Capping Remote Fill in Alleys and Driveways; and
2) Alternative RF-B: Removing Remote Fill from All Remote Fill Areas to On- or Off-Site Landfill and Treating Remote Fill Characterized as Hazardous per the 1990 ROD.

U.S. EPA has chosen to remediate the remaining remote fill areas with lead concentrations greater than 500 ppm and with paving uses (alleys, driveways, parking lots) by paving over these areas instead of excavation and off-site disposal, as originally specified in the 1990 ROD and the 1993 ESD. The bases for this decision are outlined below.

In the February 17, 1995 Proposed Plan, the following 3 alternatives were evaluated for addressing the ground water contamination:

1) Alternative G-A: Monitoring/Natural Attenuation;
2) Alternative G-B: Ground Water Containment by Pumping and Disposing into the Local Publicly-Owned Treatment Works (POTW), and Monitoring and Natural Attenuation in the Remote Fill Areas; and
3) Alternative G-C: Ground Water Containment Through a Combination of Installing a Slurry wall and Pumping and Disposing into the Local POTW, and Monitoring and Natural Attenuation in the Remote Fill Areas.

U.S. EPA has chosen to contain the ground water contamination at the Site through pumping, treatment, and discharge to the local Publicly Owned Treatment Works. The bases for this decision are outlined below.

STATEMENT OF BASES FOR RETENTION OF THE 500 PPM RESIDENTIAL SOIL CLEANUP LEVEL AND THE CAPPING REMEDY FOR THE TARACORP PILE

A. Residential Soil Cleanup Level

The March 1990 ROD specified a 500 ppm cleanup level for lead in residential soil, based on the information in the administrative record at the time. Based on all of the information in the administrative record, including new information received after March 1990, U.S. EPA retains the 500 ppm cleanup level for lead in residential soil. EPA made its decision to retain the 500 ppm cleanup level by using the nine criteria as required by CERCLA and the NCP, by evaluating the cleanup options based on all the available information and studies, guidance, and by studying the risks at the Site by using a computer model. The computer model is known as the Integrated Exposure Uptake Biokinetic (IEUBK) Model for lead in children, version .99d, designed to predict risks from lead. This was used in conjunction with the data available from the 1991 Illinois Department of Public Health (IDPH) blood study. The 1991 IDPH blood study supports retaining the 500 ppm residential soil lead cleanup level.

The bases for this decision are provided in Attachment 4 to this DD/ESD and are summarized below:

1. Consistent with the July 14, 1994 "Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities" ("July 1994 Guidance"), U.S. EPA has taken and will continue to take a "global" or multi-media approach to addressing the lead contamination at the NL Site. The primary sources of lead at the Site are interior dust and soil. The dust and the soil are the primary exposure pathways of lead to the children in the vicinity of the Site. In addition, soil lead is the primary contributor to interior dust lead in the vicinity of the NL/Taracorp smelter. U.S. EPA's cleanup goal is to limit exposure to lead such that a typical pregnant woman or child or group of similarly exposed children would have an estimated risk of no greater than 5% probability of exceeding a blood lead level of 10 ug/dl. 10 ug/dl is a level of concern for increased potential of health risks. The level of concern is for a population's blood lead levels and not meant to imply that it is a threshold for an individual's lead-induced effects. The level of concern is a scientific judgement that may have important public health implications, but not meant to imply the biological effects do not occur at lower level of exposure. In conjunction with evaluating studies and reports in the Administrative Record, U.S. EPA used the IEUBK Model to determine the appropriate soil lead cleanup level. The IEUBK Model is designed to predict blood lead concentrations for children given various concentrations of lead in the environment. Running the IEUBK Model using both site specific data as well as data compiled from comparable smelter sites (known as "default" values in the IEUBK Model) yielded a range of protective residential soil lead cleanup levels from 340 ppm to 480 ppm.

2. Using the nine criteria as required by CERCLA and the NCP, U.S. EPA selected a soil lead cleanup level for the Site of 500 ppm. Although this cleanup level is

slightly higher than the range determined from use of the IEUBK Model, this cleanup level is fully protective. First, 500 ppm is a rounded value which represents the high end of the protective soil lead values predicted from the model using site-specific values instead of default values. Second, the IDPH blood study, even with its inherent limitations, indicates that soil lead levels in excess of 500 ppm can be associated with unacceptably high blood lead concentrations in the community. Third, based upon rough cost estimates, lowering the residential soil cleanup level from 500 to 400 ppm will cost approximately 45 to 55% more, and, hence, may be considered less cost effective.

3. Additional measures ~~will be~~ taken beyond soil remediation to 500 ppm lead to assure that the selected remedy is protective. These additional measures are:

   a. Continue to work with IDPH and other agencies to address interior and exterior lead-based paint at residences where soil remediation is required. In all instances, every effort will be made to address deteriorating exterior lead-based paint prior to soil remediation in order to prevent recontamination of the soil and thus protect the remedy. These concerns were expressed in comments received during the public comment period, and this procedure was followed by U.S. EPA during previous remediations of residential soils at the NL Site;

   b. Encourage the local community to work with local health providers to implement an ongoing lead exposure reduction program;

   c. Provide a HEPA vacuum and proper training in its operation to residents whose yards are remediated in order to clean up interior house dust; and

   d. Remediate the truck lot at 1420 State Street to prevent possible lead recontamination of nearby residential properties. Additionally, U.S. EPA will inspect other areas in the immediate vicinity of the main industrial area to identify and remediate, if necessary, any additional significant sources of lead dust.

Consistent with the consensus of the experts for the City of Granite City, the PRPs, and U.S. EPA, residential soil remediation will have long-term benefits (years) for the community, including future residents, and may have short-term benefits (months) for the current residents.

B. Capping the Taracorp Pile

The discovery of ground water contamination exceeding federal and state drinking water standards associated with the Taracorp pile prompted a re-examination of the capping remedy for the Taracorp pile that was selected in the 1990 ROD. After conducting a supplemental Feasibility Study and several additional studies regarding the treatability of the Taracorp pile and likelihood of success of conventional dust suppression methods during excavation of the Taracorp pile, U.S. EPA has chosen to retain the capping remedy outlined in the 1990 ROD.

The bases for this decision are as follows:

1. The cost differential between capping and the least expensive pile removal alternative is approximately $30 million;

2. Conventional dust suppression methods did not control lead dust to acceptable levels during test trenching in the Taracorp pile; therefore, a more sophisticated system of dust suppression will likely be needed to achieve the National Ambient Quality Standard for lead during pile remediation. Given this factor, capping is the preferred alternative, involving the least potential for dust generation;

3. Once implemented, capping of the pile will be essentially equal to removal in terms of prevention of direct contact with and inhalation of contaminants from the Taracorp pile;

4. Although removal of the Taracorp pile will provide superior protection to capping in terms of reduction of ground water contamination, capping of the pile will greatly reduce infiltration and leaching of contaminants from the pile; and

5. There are no known drinking water users of ground water downgradient from the Taracorp pile/main industrial area of the Site. Illinois EPA and U.S. EPA conducted extensive surveys to verify this fact. Drinking water in the area of the Site is obtained from the Mississippi River.

   At this site, the additional $30 million for removal of the Taracorp pile will only increase the potential for generation of dust during its implementation, and thus possible recontamination of remediated residential yards near the pile. Second, the cap will greatly reduce groundwater contaminimation due to significant reduction of infiltration and leaching through the pile. Hence, little additional benefit would be realized from removal of the Taracorp pile as opposed to capping of the pile.

The liner, without a leachate collection system, under the newly expanded portions of the Taracorp pile will be retained from the 1990 ROD. The liner will retard contamination from entering the ground water, and the cap will retard infiltration through the waste material. Since the Taracorp pile extends up to ten feet below grade, the cap alone may not serve as a full containment system. Accordingly, the ground water collection system will serve the purpose of a leachate collection system. Additionally, in response to public comments regarding the effectiveness of the ground water containment system, a contingency plan is being added to the ground water remedy to require a reevaluation of the ground water remedy and further remedial action, if necessary, in the event that the cap is not effective in allowing the ground water standards to be attained via attenuation in a reasonable period of time.

SUMMARY OF ANALYSIS OF NINE EVALUATION CRITERIA

The following evaluation of the nine criteria conducted pursuant to the NCP supports U.S. EPA's determination that the 500 ppm residential soil lead cleanup and the capping of the Taracorp pile are appropriate remedial actions.

1) Overall Protection of Human Health and the Environment

Levels of protectiveness for the residential soils were selected by using the IEUBK model and evaluation of the nine criteria in accordance with the NCP and CERCLA and are based on a site-specific analysis of the data for Granite City and surrounding communities, including consideration of the results of a blood study conducted in the site area by the Illinois Department of Public Health. The 500 parts per million cleanup level for lead in residential soil will eliminate inhalation and ingestion of lead in soil at concentrations above levels which may present a risk to public health.

Regarding the Taracorp pile, capping will effectively eliminate inhalation and ingestion of lead from waste materials in the pile. Once implemented, capping will also eliminate the generation of lead dust from the pile. Further, capping will significantly reduce the amount of water infiltration into the pile and, thus, the amount of leachate generated from the pile. The liner under the newly generated portions of the capped pile, or cell, will also greatly reduce the impact of the contaminants from the pile to site ground water.

2) Compliance with State and Federal Regulations (ARARS)

There are no specific Applicable or Relevant and Appropriate Regulations (ARARs) for lead in residential soil (CERCLA Section 121, 42 USC 9621, and the NCP). The 500 ppm lead cleanup level for residential soil, and provisions to provide a HEPA vacuum to residents and to address paint contamination within the site area, were selected by using site-specific factors, the IEUBK model and evaluation of the nine criteria in accordance with the NCP and CERCLA.

The cap for the Taracorp pile will comply with all applicable Resource Conservation and Recovery Act requirements, and dust control measures will be implemented during remedial activities to within the National Ambient Air Quality Standards and to prevent recontamination.

The SLLR pile and the associated contaminated soils from the industrial area will be consolidated with the Taracorp pile. Because the SLLR pile and the contaminated soils comprise continuous zone of contamination created by site operations, the newly created portion of the Taracorp pile is not a new unit subject to full RCRA regulation pursuant to 40 CFR Subpart L for Waste Piles or Subpart N for Landfills.

Both the Taracorp pile and the cell will utilize a RCRA-compliant Subtitle C cap to reduce the direct contact/ingestion threat, air emissions and infiltration of water through the waste material to protect the groundwater, and the newly created portions will be provided with a liner for additional protection against leaching and as a barrier to further protect the groundwater. Proper long-term operation and maintenance of the pile will be instituted.

The ground water extraction system to be placed near the pile will serve as a "leachate collection system", to collect contaminated leachate emanating from the pile, and newly created portions of the pile. Groundwater monitoring in the area will serve to evaluate the remedial action and verify the effectiveness of the collection system. A contingency plan will provide for reevaluation and, if necessary, further remedial action for the ground water in the event that the cap is ineffective in reducing the quantity of leachate to levels that will allow the ground water cleanup standards to be achieved within a reasonable period of time.

Institutional controls such as site access restrictions, restrictive covenants, deed restrictions and property transfer restrictions will be implemented for the industrial area to assure that the remedy is effective.

It is impracticable to retrofit the more highly contaminated existing pile with either a liner or leachate collection system, and the newly expanded portions will add very little to the existing potential for leachate generation since U.S. EPA is planning ~~on~~ putting waste material with much lower average lead concentration in a cell next to the existing Taracorp pile which has a much higher lead concentration. As stated above, there will be a liner under the cell. However, there will be no liner under the Taracorp pile because the pile is large, very dense and some of the waste is below grade; hence, it would be impossible to place a liner and leachate collection system under the existing Taracorp pile without physically moving it. As described below, it would not be cost effective to move the pile. Movement of the pile would also increase the potential to generate dust and recontaminate nearby residential properties.

3) <u>Reduction of Toxicity, Mobility, or Volume Through Treatment</u>

The selected remedy does not call for treatment of the residential soils or the waste materials in the Taracorp pile. However, cleaning up residential soils to 500 ppm lead will eliminate the toxicity, mobility and volume of lead-contaminated soils which pose an unacceptable health risk to children in the site area. Likewise, the cap on the Taracorp pile will reduce the mobility of the lead in the Taracorp pile by providing a barrier to both infiltration into and release of lead dust from the pile.

4) <u>Short-Term Effectiveness</u>

Residential soil remediation will have short-term benefits (i.e., months) for the current residents. The removal of the most highly lead contaminated soils first will eliminate the exposure of children to lead in residential soil at the site at concentrations that pose the highest health risk to children. U.S. EPA presence in the community has had a positive impact with respect to making residents aware of the dangers of lead.

Implementation of the residential soil cleanup will create the potential for releases of lead dust to the air on the very short term. This potential will be eliminated by the use of effective dust control measures. These measures have already been effective during the remediation of approximately 50 residences which have been completed thus far. Air monitoring results during these cleanups have indicated that lead air emissions were well within the applicable standards on every occasion.

Residential soil cleanup will also slightly increase truck traffic and therefore create the potential for increased traffic related accidents on the very short term. This potential increase is not significant given that Granite City has considerable truck traffic in the site vicinity due to many currently operating industries, including a large steel mill. In addition, procedures in place during the cleanup of approximately 50 residences completed to date have resulted in zero traffic-related accidents. These procedures will continue to be implemented during remaining residential soil cleanup activities.

Placing of the cap on the Taracorp pile along with pre-capping grading activities will create the potential for dust generation and runoff from the pile. Runoff will not be a significant problem since site runoff pools in low spots and does not leave the site.

Dust generation is of great importance to U.S. EPA, and dust control measures will be implemented to control dust emissions to acceptable levels, both for attainment of ARARs and to prevent recontamination of nearby residences which have already been cleaned up to 500 ppm lead. If initial dust control measures, such as wetting with water, are not effective, work will be halted and more sophisticated measures will be taken. It should be noted that the potential for dust generation is much less for capping the pile than for the pile removal/recycling options researched in the Second Addendum to the Feasibility Study.

5) Long-Term Effectiveness

The residential soil and pile remediation will have long-term benefits (i.e., years) for the community, including future residents. Both the residential soil cleanup and capping of the Taracorp pile will be effective in the long-term because removing soil in excess of 500 ppm will permanently address the exposure of children to lead in residential soil at the site at concentrations that pose a health risk and capping the pile, along with the required operation and maintenance of the cap, will prevent the generation of airborne lead from the pile and ingestion of lead in the pile and will significantly reduce the infiltration into, and thus the leaching of lead from, the pile. This, in conjunction with the ground water remedy described below, will provide an effective long-term remedy for site ground water contamination.

6) Implementability

The residential soil cleanup and capping remedies both utilize proven technologies that are readily implementable.

7) Cost

The cost of cleaning up to 500 ppm amounts to remediating approximately 1300 residences. The cost estimates range from $15,000,000 to $42,000,000. The higher cost estimate is based upon actual costs incurred to date during the period where the U.S. EPA was subject to a court proceeding for a Temporary Restraining Order (TRO) brought by the City of Granite City. The

$42,000,000 cost estimate was prorated for all work and is not considered to be representative of normal operations due to excessive mobilization and demobilization costs and startup and shutdown periods brought about by the TRO proceedings.

The cost of cleaning up to 500 ppm is greater than that for a higher cleanup level. This additional cost is justified since allowing higher lead levels to remain at site residences will simply not provide adequate protection of human health. The bases for the selection of the 500 ppm cleanup level are outlined in Attachment 4 and the preceding section of this DD/ESD.

The cost of capping the Taracorp pile (approximately $4.8 million) is significantly less than that for the cheapest pile removal scenario (approximately $34.6 million). Given the fact that capping provides overall protection of human health and the environment, cost was a strong factor in selecting capping for the Taracorp pile.

8) State Acceptance

As was the case with the March 1990 ROD, the Illinois Environmental Protection Agency fully supports the 500 ppm residential soil cleanup level, as well as U.S. EPA's decision to cap the Taracorp pile.

9) Community Acceptance

After personal visits by U.S. EPA employees with at least 400 of the residents in the cleanup area (approximately 1300 residences will require cleanup using a 500 ppm lead level), it is clear that the majority of these residents support the 500 ppm soil cleanup level. The support is overwhelming in the areas immediately adjacent to the Taracorp property. This support is evident in the transcript of the public meetings for the residential soil cleanup level, the petitions signed by residents opposing the Granite City government's (City's) attempts to halt cleanup activities in the residential areas, and the fact that a significant number of residents travelled to Benton, Illinois (two hours away) to attend a court hearing and register their opposition regarding the City's efforts to halt the residential cleanups. The City of Madison, Illinois signed an access agreement to allow U.S. EPA to clean up the city easement area of properties to which the resident granted access to U.S. EPA to clean up the residential soil. The City of Venice, Illinois has been fully cooperative in granting U.S. EPA access for residential cleanup activities. By contrast, the City of Granite City alone has strongly opposed U.S. EPA's efforts to clean up residential soil.

Regarding the Taracorp pile, the community is not clearly for or against capping the pile. In the past (1990), based on public comments received, the majority of people in the area wanted the pile removed from the area; however, interest in the pile issue has fallen off dramatically, as evidenced by the low attendance at the public meeting for the proposed remedy for the pile and the submission of only five public comments on the matter. Given the low level of input on the pile remedy during the public comment period, it is difficult to gage the public opinion on capping. Individual conversations with residents have revealed that many of them would still like the pile removed, but many have also changed their mind to support capping when they became aware of the $30 million cost differential between capping and pile removal.

DESCRIPTION OF THE SIGNIFICANT DIFFERENCES AND THE BASES FOR THE DIFFERENCES

In accordance with Section 117(c) of the Comprehensive Environmental Response, Compensation, and Liability Act, as amended (CERCLA), and consistent with Section 300.435(c)(2)(i) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), U.S. EPA has determined that the changes to the remedy constitute a significant change to the remedy required in the March 30, 1990 ROD. The changes, however, are not a fundamental reconsideration of the basic remedy selection on which comment was taken. This ESD pertains to the changes discussed below.

A. Remote Fill Areas

After review of the February 1995 Second Feasibility Study Addendum, the Proposed Plan, and comments received during the public comment period, U.S. EPA has chosen to remediate the remaining remote fill areas with lead concentrations greater than 500 ppm and with paving uses (alleys, driveways, parking lots) by paving over these areas instead of excavation and off-site disposal, as originally specified in the 1990 ROD and the 1993 ESD. All other remaining remote fill areas with lead concentrations exceeding 500 ppm (i.e., residential lots) will still be excavated, subject to the current practice of limiting excavation depth to three feet, and disposed of off-site. The bases for this difference are as follows:

1. U.S. EPA has already remediated or is currently remediating all of the most highly contaminated remote fill areas that have been identified to date, with only one exception in Venice on Slough Road,

2. The number of remote fill areas to be excavated has escalated from the 1990 ROD estimate of 18 to the current estimate of over 100, and

3. Given this nearly fivefold increase in the number of locations to be remediated, it is not cost effective to continue excavation and off-site disposal of the remaining remote fill areas with paving uses. Paving and maintaining this surface cover will provide adequate protection from ingestion of battery case materials and surrounding soils in these alleys, driveways, and parking lots with scattered contamination and lead concentrations that do not greatly exceed the 500 ppm lead cleanup level.

Any remote fill areas with paving uses that are newly identified after signature of this DD/ESD and with a lead concentration greater than 500 ppm will be reviewed on a case-by-case basis to determine whether paving or excavation is appropriate. Such areas may include areas that are uncovered by intrusive activities (e.g. utility excavations) in the future.

B. Ground Water

After review of the February 1995 Second Feasibility Study Addendum (Second FS Addendum), Proposed Plan, and comments received during the public comment period, U.S. EPA has chosen to contain the ground water contamination at the Site through pumping, treatment, and discharge to the local Publicly Owned Treatment Works. The bases for this difference are:

1. The ground water remedy is linked to the capping remedy for the Taracorp pile and basically will serve as a leachate collection system, ensuring that the capping remedy is effective in the long term.

2. Natural attenuation alone is unacceptable because it does not meet ARARs and will not be acceptable to the Illinois EPA; and

3. Given that there are no downgradient users of drinking water in the site area, the additional cost of implementing a more elaborate remedy cannot be justified.

As part of the selected ground water remedy, further downgradient ground water monitoring will be needed to determine the extent of the ground water contamination plume, and the cost estimate in the Second FS Addendum will be adjusted accordingly if more than four pumping wells will be necessary to contain the plume. Additionally, provisions for shutting off the containment system will be developed (e.g., if ARARs are achieved at the point(s) of compliance).

SUMMARY OF ANALYSIS OF NINE EVALUATION CRITERIA

1) Overall Protection of Human Health and the Environment

Paving of remote fill areas that exceed 500 ppm and have current paving uses (i.e. driveways, alleys, and parking lots), along with operation and maintenance of the paving surface, will provide overall protection of human health by providing an effective barrier between the battery chips and the receptor (children).

Containment of the contaminant plume, in conjunction with the fact that downgradient users are all drinking city water obtained from the Mississippi River, also provides overall protection of human health and the environment.

2) Compliance with State and Federal Regulations (ARARs)

There are no ARARs for remediation of lead contaminated soil and battery chips; however, the battery chip remediation program is consistent with all applicable U.S. EPA guidance.

Containment of the contaminated ground water will meet all ARARs.

3) Reduction of Toxicity, Mobility, or Volume Through Treatment

The selected remedy does call for treatment for some of the remote fill areas and will reduce the mobility of lead from the fill which pose an unacceptable health risk to children in the site area.

For those areas which will be paved, instead of off-site disposal, paving will reduce the mobility of lead.

Likewise, containment of the ground water plume will halt the migration of the plume and reduce the volume of contaminated ground water, and the extracted ground water will be treated, as necessary, prior to discharge to the POTW.

4) Short-Term Effectiveness

Paving of remote fill areas with current paving uses will present less potential for producing lead dust than removal. Even so, dust control measures, which have been very effective during battery chip removal actions, will be used to control lead dust emissions to within applicable standards.

Ground water is currently being monitored and there are no known users of the ground water for drinking purposes. The monitoring system will evaluate the plume characteristics on the short term. Ground water containment presents minimal potential for short-term impacts.

5) Long-Term Effectiveness

This remedy utilizes permanent solutions to the maximum extent practicable for the Site. The long term exposure will be eliminated for the remote fill areas.

Ground water will be contained to eliminate migration of lead. U.S. EPA and IEPA believe that the remedy remains protective of human health and the environment and is enhanced by addressing ground water contamination that was not previously discovered.

6) Implementability

Both paving of remote fill areas with current paving uses and ground water containment are proven technologies that are readily implementable.

7) Cost

Paving of a portion of the remote fill areas as opposed to excavation will be more cost effective. The current cost estimate for completing remediation of all remote fill areas is $18,000,000. The increase in cost for remediation of remote fill areas is due to the increase in the number of these areas that must be remediated as compared to the estimates in the 1990 ROD.

Ground water containment and monitoring will cost approximately $3 million. This remedy is cheaper than the other remedies considered in the proposed plan and is more cost effective.

8) State Acceptance

As was the case with the March 1990 ROD, the Illinois Environmental Protection Agency (IEPA) fully supports the remedies for the remote fill areas. IEPA also supports the remedy for the contaminated ground water at the site.

9) Community Acceptance

No comments were received regarding paving of remote fill areas, so it is hard to gage community acceptance of this minor change in the remedy. Few comments were received regarding containment of the ground water plume. The comments that were received indicated a split opinion on containment versus attenuation only. Concerns were also raised regarding the cost estimates for ground water containment in the Second Feasibility Study. These comments are addressed in the Responsiveness Summary Regarding the Taracorp Pile, Remote Fill Areas, and Ground Water, which comprises Attachment 3 to this DD/ESD.

SUPPLEMENT TO THE U.S. EPA ADMINISTRATIVE RECORD
NL INDUSTRIES/TARACORP
GRANITE CITY, ILLINOIS

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
1.	06/25/90	U.S. EPA	Special Notice for RD/RA with attachments	122	PRPs
2.	08/31/90-10/24/90	Var.	Letter with attachments re: Certain PRP Responses to the Special Notice	198	B. Bradley, U.S. EPA
3.	09/11/90-12/24/90	U.S. EPA	Letters re: EPA's Response to Certain PRP Offers	12	PRPs
4.	11/27/90	U.S. EPA	Administrative Order with attachments	96	PRPs
5.	10/30/90	B. Bradley, U.S. EPA	Memorandum re: Additional remediation areas in Granite City, Madison, Venice and Eagle Park Acres, IL	1	File
6.	07/11/89-10/30/90	Var.	NL Industries/Taracorp Granite City, IL Administrative Record - The amended page 13 of the AR index	1	Var.
7.	07/11/89-07/12/89	B. Bradley, U.S. EPA	Trip Report - Venice, IL	12	
8.	06/22/90		Waste-in List Generator Ranking Summary	15	
9.	08/30/90-03/08/91	PRPs	Letters with attachments re: Certain PRP Responses to EPA's Administrative Order	737	U.S. EPA
10.	12/21/90-03/29/91	U.S. EPA	Letters with attachments re: EPA's Responses to Certain PRP Administrative Order Offers	47	PRPs
11.	1992	CH2 M Hill and U.S. EPA	"Sampling Artifacts and Potential Transport of Metal Colloids - San Fernando Valley Basin, California"	8	
12.	01/20/93	B. Culnan, IEPA	Letter enclosing Illinois Groundwater Regulations	55	B. Bradley, U.S. EPA
13.	02/17/92	Dr. R. Kerr, U.S. EPA	"Highlights - Robert S. Kerr Environmental Research 1992"	1	

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
14.	11/92	Woodward-Clyde	"Supplemental Groundwater Investigation-NL/Taracorp Superfund Site - Granite City, Illinois	512	
15.	12/89	U.S. EPA	Excerpts from "Risk Assessment Guidance for Superfund - Volume I"	4	
16.	3/89	R. Puls and M. Barcelona, U.S. EPA	"Superfund Ground Water Issue - Ground Water Sampling for Metals Analyses"	6	
17.	10/14/92	U.S. EPA	Risk Assessment Teleconference for Superfund - Meeting Minutes (RATS)	3	
18.	11/07/91	C. Sunich - Mullen, U.S. EPA	Meeting Notes of RATS - 10/08/91	4	
19.	1987	O. Braids, et al.	"Should Ground Water Samples from Monitoring Wells be Filtered Before Laboratory Analysis?"	10	
20.	04/23/90	U.S. EPA	"EPA Region III QA Directives"	2	
21.	02/16/93	OHM	"Final Work Plan for Remediation of Locations in Granite City, Madison, and Venice, Illinois, Associated with NL Industries/Taracorp Superfund Site"	418	USACE
22.	03/29/90		55 Fed. Reg. 11798 "Hazardous Waste Management System; Identification and Listing of Hazardous Wastes; Toxicity Characteristics Revisions"	80	
23.	1992	R. Puls, et al.	"Metals in Groundwater: Sampling Artifacts and Reproducibility"	14	
24.	07/31/92	D. Forman, U.S. EPA	"Filtered/Unfiltered Groundwater Analysis-Risk Assessment Perspectives"	2	D. Willis, U.S. EPA
25.	04/92	U.S. EPA	"Drinking Water Regulations and Health Advisories"	13	
26.	1992	Kearl, P., et al.	Article: "Suggested Modifications to Ground Water Sampling Procedures Based on Observations from the Colloidal Borescope" (GWMR)	7	
27.	1992	Puls, R., et al.	Article: "Acquisition of Representative Groundwater Quality Samples for Metals" (GWMR)	11	
28.	12/90	R. Puls, et al.	"Environmental Research Brief"	12	

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
29.	07/91	Puls, R., et al.	"Environmental Research Brief"	12	
30.	05/10/93-05/15/93	B. Bradley and B. Colman	U.S. EPA/IEPA Approval Letters for Final Work Plan for the Removal of Hard Rubber Battery Case Material	2	J. Hoban and B. Bradley
31.	05/10/93	S.L. Carlock, USACE	Letter Enclosing Cost Differential Estimate	2	B. Bradley, U.S. EPA
32.	12/09/91	W.T. Ballard, U.S. EPA	Letter re: Ground Water Sampling for Metals	7	R. Lester, WPAFB
33.	1992	Puls, R., and Powell, R.	Article: "Transport of Inorganic Colloids Through Natural Aquifer Material: Implications for Contaminant Transport" (Environ. Sci. Technol.)	8	
34.		Angle, C., et al.	Abstract: "Kinetics of Childhood Lead: The Omaha Duplicate Diet Study"	5	
35.	1989	Bornschein, R., et al.	Article: "Soil Lead – Blood Lead Relationship in a Former Lead Mining Town" (Environ. Geochem. Health)	12	
36.		Lutz, P., et al.	Article: "Immunity in Children with Exposure to Environmental Lead: I. Effects on Cell Numbers and Cell-Mediated Immunity" (Draft)	21	
37.	1993	National Academy of Sciences	Publication: "Measuring Lead Exposure in Infants, Children, and Other Sensitive Populations" (National Academy Press)	348	
38.	1981-1992	Watt, T., et al.	Excerpt from Journal Article: "Lead Contamination of U.K. Dusts and Soils and Implication for Childhood Exposure: An Overview of Work of the Environmental Geo-chemistry Research Group" (Imperial College, London)	1	
39.	05/61	Kehoe, R.	Lecture: "The Metabolism of Lead in Man in Health and Disease" (Harben Lecture, 1960)	21	
40.	05/74	Rosen, J. and Trinidad, E.	Journal Article: "Significance of Plasma Lead Levels in Normal and Lead-Intoxicated Children" (Environmental Health Perspectives)	6	
41.	1975	Barry, P.	Journal Article: "A Comparison of Concentrations of Lead in Human Tissues" (British Journal of Industrial Medicine)	22	

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
42.	01/76	Barry, P.	Journal Article: Complete Set of Data in Support of "A Comparison of Concentrations of Lead in Human Tissues" (British Journal of Industrial Medicine)	35	
43.	1970	Barry, P. and Mossman, D.	Journal Article: "Lead Concentrations in Human Tissues" (British Journal of Industrial Medicine)	13	
44.	08/77	Damstra, T.	Journal Article: "Toxicological Properties of Lead" (Environmental Health Perspectives)	11	
45.	08/77	Yankel, A., et al.	Journal Article: "The Silver Valley Lead Study: The Relationship Between Childhood Blood Lead Levels and Environmental Exposure" (Journal of the Air Pollution Control Association)	5	
46.	1978	Ziegler, E., et al.	Journal Article: "Absorption and Retention of Lead by Infants" (Pediat. Res.)	6	
47.	07/79	Barltrop, D. and Meek, F.	Journal Article: "Effect of Particle Size on Lead Absorption" (Arch. Environ. Health)	6	
48.	04/80	Needleman, H.	Journal Article: "Lead Exposure and Human Health: Recent Data on an Ancient Problem" (Technology Review)	7	
49.	1981	Barry, P.	Journal Article: "Concentrations of Lead in the Tissues of Children" (British Journal of Industrial Medicine)	11	
50.	1981	Barry, P.	Journal Article: Additional Set of Data in Support of "Concentrations of Lead in the Tissue of Children" (British Journal of Industrial Medicine)	8	
51.	1981	Needleman, H. and Landrigan, P.	Journal Article: "The Health Effects of Low Level Exposure to Lead" (Ann. Review of Public Health)	20	
52.	1982	Needleman, H.	Journal Article: "The Neurobehavioral Consequences of Low Lead Exposure in Childhood" (Neurobehavioral Toxicology and Teratology)	4	
53.	1982	Stark, A., et al.	Journal Article: "The Relationship of Environmental Lead to Blood-Lead Levels in Children" (Environmental Research)	12	
54.	09/02/82	Mahaffey, K., et al.	Journal Article: "National Estimates of Blood Lead Levels: United States, 1976-1980" (New England Journal of Medicine)	7	

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
55.	1983	Kneip, T., et al.	Journal Article: "Biokinetic Modelling for Mammalian Lead Metabolism" (Neurotoxicology)	4	
56.	1983	Needleman, T.	Journal Article: "Lead at Low Dose and the Behavior of Children" (Acta Psychiat. Scand.)	12	
57.	09/83	Rye, J., et al.	Journal Article: "Dietary Intake of Lead and Blood Lead Concentration in Early Infancy" (Am J Dis Child)	6	
58.	1984	Angle, C., et al.	Journal Article: "Omaha Childhood Blood Lead and Environmental Lead: A Linear Total Exposure Model" (Environmental Research)	11	
59.	1984	Brunekreef, B.	Journal Article: "The Relationship Between Air Lead and Blood Lead in Children: A Critical Review" (Sci. Total Environ.)	45	
60.	1984	Rabinowitz, M., et al.	Journal Article: "Variability of Blood Lead Concentrations During Infancy" (Arch. Environ. Health)	4	
61.	1985	Bornschein, R., et al.	Journal Article: "The Cincinnati Prospective Study of Low-Level Lead Exposure and its Effects on Child Development: Protocol and Status Report" (Environmental Research)	15	
62.	1985	Bornschein, R., et al.	Journal Article: "The Influence of Social and Environmental Factors on Dust Lead, Hand Lead and Blood Lead Levels in Young Children" (Environmental Research)	10	
63.	1985	Marcus, A.	Journal Article: "Multicompartment Kinetic Models for Lead: I. Bone Diffusion Models for Long-Term Retention" (Environmental Research)	18	
64.	10/85	Rabinowitz, M., et al.	Journal Article: "Lead in Milk and Infant Blood: A Dose-Response Model" (Archives of Environmental Health)	4	
65.	1986	Bornschein, R., et al.	Paper: "Exterior Surface Dust Lead, Interior House Dust Lead and Childhood Lead Exposure in an Urban Environment" (Draft)	12	
66.	1986	Creswell, P., et al.	Journal Article: "Chronic Lead Nephropathy in Queensland: Alternative Methods of Diagnosis" (Australian/New Zealand Journal of Medicine)	7	
67.	1986	Koh, T. and Babidge, P.	Journal Article: "A Comparison of Blood Levels in Dogs from Lead-Mining, Lead-Smelting, Urban and Rural Island Environment" (Aust. Vet. J.)	4	
68.	1986	Rabinowitz, M., et al.	Journal Article: "Occurrence of Elevated Protoporphyrin Levels in Relation to Lead Burden in Infants" (Environmental Research)	5	
69.	1986	U.S. EPA	Air Quality Criteria for Lead: Volumes 1, 2, 3 and 4 and supplement	1327	

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
70.	05/86	Hamir, A. and Handson, P.	Journal Article: "Time Required for Elevated Blood Lead Concentrations to Return to Normal in Dogs" (Australian Veterinary Journal)	2	
71.	06/86	Bornschein, R., et al.	Paper: Exterior Surface Dust Lead, Interior House Dust Lead and Childhood Lead Exposure in an Urban Environment (Conference on Trace Metals in Environmental Health-XX)	13	
72.	06/06/86	Bellinger, D., et al.	Journal Article: "Correlates of Low-Level Lead Exposure in Urban Children at 2 Years of Age" (Pediatrics)	8	
73.	1991	Mahaffey, K.	Journal Article: "Biokinetics of Lead During Pregnancy"	2	
74.	1987	Needleman, H.	Journal Article: "Introduction: Biomakers in Neurodevelopmental Toxicology" (Environmental Health Perspectives)	4	
75.	1987	Schutz, A., et al.	Journal Article: "Kinetics of Lead in Blood after the End of Occupational Exposure" (Scand. J. Work Environ. Health)	10	
76.	1988	Brockhaus, A., et al.	Journal Article: "Exposure to Lead and Cadmium of Children Living in Different Areas of North-West Germany: Results of Biological Monitoring Studies 1982-1986" (Occupational Environmental Studies)	12	
77.	1988	Fergusson, D., et al.	Journal Article: "A Longitudinal Study of Dentine Lead Levels, Intelligence, School Performance and Behavior; Part III: Dentine Lead Levels and Attention/Activity" (J. Child Psychol. Psychiatr.)	14	
78.	08/25/88	McMichael, A., et al.	Journal Article: "Port Pirie Cohort Study: Environmental Exposure to Lead and Children's Abilities at the Age of Four Years" (New England Journal of Medicine)	8	
79.	1988	Nriagu, J. and Pacyna, J.	Journal Article: "Quantitative Assessment of Worldwide Contamination of Air, Water and Soils by Trace Metals" (Nature)	6	
80.	1988	Rosen, J.	Publication Excerpt: "The Toxicological Importance of Lead in Bone: The Evolution and Potential Uses of Bone Lead Measurements by X-Ray Fluorescence to Evaluate Treatment Outcomes in Moderately Lead Toxic Children" (Biological Monitoring of Toxic Metals)	10	
81.	1989	Marcus, A. and Cohen, J.	Paper: "Modelling the Blood Lead—Soil Lead Relationship" (Proceedings: Environmental Geochemistry and Health)	14	
82.	12/88	Wittmers, L., et al.	Journal Article: "Lead in Bone: IV. Distribution of Lead in the Human Skeleton" (Archives of Environmental Health)	11	

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
83.	1989	Dietrich, K., et al.	Publication Excerpt: "Neurobehavioral Effects of Fetal Lead Exposure: The First Year of Life" (Lead Exposure and Child Development)	13	
84.	1989	Grant, L. and Davis, J.	Publication Excerpt: "Effects of Low-Level Lead Exposure on Paediatric Neurobehavioral Development: Current Findings and Future Directions" (Lead Exposure and Child Development)	68	
85.	1989	Hansen, O., et al.	Journal Article: "A Neuropsychological Study of Children with Elevated Dentine Lead Level: Assessment of the Effects of Lead in Different Socio-Economic Groups" (Neurotoxicol. Teratol.)	9	
86.	1989	Hatzakis, A., et al.	Publication Excerpt: "Psychometric Intelligence Deficits in Lead-Exposed Children" (Lead Exposure and Child Development)	14	
87.	1989	Madhavan, S., et a..	Journal Article: "Lead in Soil: Recommended Maximum Permissible Levels" (Environmental Research)	7	
88.	1989	Mushak, P.	Publication Excerpt: "Biological Monitoring of Lead Exposure in Children: Overview of Selected Biokinetic and Toxicological Issues" (Lead Exposure and Child Development)	18	
89.	1989	Mushak, P. and Crocetti, A.	Review: "Determination of Numbers of Lead-Exposed American Children as a Function of Lead" Source: "Integrated Summary of a Report to the U.S. Congress on Childhood Lead Poisoning" (Environmental Research)	20	
90.	1989	Mushak, P., et al.	Report: "Prenatal and Postnatal Effects of Low-Level Lead Exposure: Integrated Summary of a Report to the U.S. Congress on Childhood Lead Poisoning" (Environmental Research)	26	
91.	1989	Rabinowitz, M., et al.	Journal Article: "Blood Lead–Tooth Lead Relationship Among Boston Children" (Bulletin of Environmental Contamination and Toxicology)	4	
92.	1989	Thompson, G., et al.	Journal Article: "Blood-Lead Levels and Children's Behavior: Results from the Edinburgh Lead Study" (J. Child Psychol. Psychiatr.)	14	
93.	01/89	Rosen, J., et al.	Journal Article: "L-Line X-Ray Fluorescence of Cortical Bone Lead Compared with the CaNa2EDTA Test in Lead-Toxic Children: Public Health Implications" (Proc. Nat'l Acad. Sci. USA)	5	
94.	1990	Dietrich, K., et al.	Journal Article: "Lead Exposure and Neurobehavioral Development in Later Infancy" (Environmental Health Perspectives)	8	
95.	1990	Winneke, G., et al.	Journal Article: "Results from the European Multicenter Study on Lead Neurotoxicity in Children: Implications for Risk Assessment" (Neurotoxicol. Teratol.)	7	
96.	09/27/90	Mushak, P.	Paper: "Gastro-Intestinal Absorption of Lead in Children and Adults: Overview of Biological and Biophysico-Chemical Aspects" (Symposium on the Bioavailability and Dietary Exposure of Lead)	37	

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
97.	11/90	Bornholz, A. and Marcus, A.	Paper: "Inter-Site Comparisons of Environmental Lead Uptake" (Symposium on Bioavailability)	82	
98.	1991	Bellinger, D., et al.	Journal Article: "Weight Gain and Maturity in Fetuses Exposed to Low Levels of Lead" (Environ. Res.)	8	
99.	1991	ATSDR	Pamphlet: "Important Facts About Childhood Lead Poisoning Prevention"	2	
100.	03/91	Mushak, P.	Monograph: *Gastro-Intestinal Absorption of Lead in Children and Adults: Overview of Biological and* Biophysico-Chemical Aspects (Chemical Speciation and Bioavailability)	18	
101.	1991	Nilsson, U.	Journal Article: "Kinetics of Lead in Bone and Blood after the End of Occupational Exposure" (Pharmacology & Toxicology)	8	
102.	1991	Rabinowitz, M.	Journal Article: "Toxicokinetics of Bone Lead" (Environmental Health Perspectives)	5	
103.	1991	Rosen, J., et al.	Journal Article: "Sequential Measurements of Bone Lead Content by L X-Ray Fluorescence in CaNa2 EDTA-Treated Lead-Toxic Children" (Environmental Health Perspectives)	6	
104.	02/21/91	Reilly, W., U.S. EPA	Testimony of the Administrator/U.S. EPA Before the Committee on Environment and Public Works, U.S. Senate	24	
105.	02/26/91	OPTS/U.S. EPA	Memorandum re: Final Agency Lead Strategy	44	
106.	08/29/91	OSWER/U.S. EPA	Memorandum re: Update on OSWER Soil Lead Cleanup Guidance	4	
107.	10/91	ATSDR	Statement: "Preventing Lead Poisoning in Young Children"	118	
108.	12/03/91	U.S. EPA	Report: "Analysis of Lead in Soil and Dust Data"	85	
109.	1992	American Academy of Pediatrics	Report: "Lead Poisoning: From Screening to Primary Prevention;" Report of Committee on Environmental Health (Pediatr.)	8	
110.	1992	Baghurst, P., et al.	Journal Article: "Environmental Exposure to Lead and Children's Intelligence at the Age of Seven Years" (New England Journal of Medicine)	6	
111.	1992	Beck, B.	Journal Article: "An Update on Exposure and Effects of Lead" (Fundamental and Applied Toxicology)	8	

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
112.	12/92	Bellinger, D., et al.	Journal Article: "Low-Level Lead Exposure, Intelligence and Academic Achievement: A Long-Term Follow-Up Study" (Pediatr.)	7	
113.	1992	Freeman, G., et al.	Journal Article: "Relative Bioavailability of Lead from Mining Waste Soil in Rats" (Fundamental and Applied Toxicology)	11	
114.	08/03/92	Rothenberg, S., et al.	Paper: "Simple Modeling of Material Lead Levels During Pregnancy: The Role of Extrinsic and Intrinsic Factors" (International Conference on Lead and Other Trace Substances)	14	
115.	08/04/92	Marcus, A.	Presentation: "Comparative Approaches to Superfund Site Assessments for Young Children Exposed to Lead" (Proceedings: Environmental Geochemistry and Health)	23	
116.	11/92	Wasserman, G., et al.	Journal Article: "Independent Effects of Lead Exposure and Iron Deficiency Anemia on Developmental Outcome at Age 2 Years" (Journal of Pediatrics)	10	
117.	12/08/92	IDPH	Madison County, Granite City, IL; Lead Exposure Study (Draft)	193	
118.	1993	Dietrich, K., et al.	Journal Article: "The Developmental Consequences of Low to Moderate Prenatal and Postnatal Lead Exposure: Intellectual Attainment in the Cincinnati Lead Study Cohort Following School Entry" (Neurotoxicol. Teratol.)	6	
119.	04/93	ATSDR/US DHHS	Toxicological Profile for Lead	330	
120.	04/07/93	Ruff, H., et al.	Journal Article: "Declining Blood Lead Levels and Cognitive Changes in Moderately Lead-Poisoned Children" (Journal of the American Medical Association)	6	
121.	04/14/93	T. Long, IDPH	Letter re: Request for ATSDR's Review of the Multi-State Lead Exposure Study	1	F. Stallings, ATSDR
122.	06/08/93	Frank, A.	Peer Review Comment Forms to ATSDR re: (1) Lead and Cadmium Exposure Study; (2) Lead Exposure Study, Madison County; and (3) Management of Children with Slightly Elevated Blood Lead Levels	5	
123.	07/93	OERR/U.S. EPA	Urban Soil Lead Abatement Demonstration Project, Volume 1: Integrated Report [Review Draft] (EPA/600/AP-93/001a)	199	
124.	07/93	OERR/U.S. EPA	Urban Soil Lead Abatement Demonstration Project, Volume 2: Boston Report (EPA/600/AP-93/001b)	736	
125.	07/93	OERR/U.S. EPA	Urban Soil Lead Abatement Demonstration Project, Volume 3: Baltimore Report (EPA/600/AP-93/001c)	548	
126.	07/93	OERR/U.S. EPA	Uban Soil Lead Abatement Demonstration Project, Volume 4: Cincinnati Report (EPA/600/AP-93/001d)	272	

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
127.	07/23/93	Londergan, R.	Peer Review Comment Forms to ATSDR re: (1) Lead and Cadmium Exposure Study; (2) Lead Exposure Study, Madison County; and (3) Management of Children with Slightly Elevated Blood Lead Levels	16	
128.	1994	Marcus, A. and Elias, R.	Publication Excerpt: "Estimating the Contribution of Lead-Based Paint to Soil Lead, Dust Lead and Childhood Blood Lead" (Lead in Paint, Soil and Dust)	12	
129.	02/94	IDPH	Madison County Lead Exposure Study; Granite City, IL	256	
130.	02/94	OERR/U.S. EPA	Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children (Publication 9285.7-081)	256	
131.	12/93	Holmes, H. and Breen, B.	Journal Article: "Getting the Lead Out" (Garbage) with responses	11	
132.	03/09/94	Stipp, D.	Journal Article: "Probe Finds Errors, but No Misconduct in Work by Lead-Poisoning Researcher" (Wall Street Journal)	1	
133.	03/23/94	OSWER/U.S. EPA	Memorandum re: Transmittal of Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children and IEUBK Model, Version 0.99d	2	Var.
134.	04/84	Rabinowitz, M., et al.	Journal Article: "Variability of Blood Lead Concentrations During Infancy" (Archives of Environmental Health)	4	
135.	05/23/94	Marcus, A., et al.	Comments on Madison County Lead Exposure Study	35	
136.	05/24/94	P. Van Leeuwen, U.S. EPA	Letter to J. Lumpkin, IDPH, re: U.S. EPA Comments on the Draft Lead Exposure Study	1	J. Lumpkin, IDPH
137.	06/94	ATSDR	Report: "Multisite Lead and Cadmium Exposure Study with Biological Markers Incorporated" (Draft)	256	
138.	06/03/94	Von Lindern, I.	Paper: "Reducing Children's Blood Lead Levels at the Bunker Hill Superfund Site in Northern Idaho, USA Through Health Intervention and Soil/Dust Source Control Measures" (1994 International Lead Abatement and Remediation Conference)	23	
139.	06/15/94	S. Siegel, U.S. EPA	Letter re: Draft Lead Exposure Study	1	D. Webb, IDPH
140.	07/14/94	OSWER/U.S. EPA	Memorandum re: Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities (OSWER Directive #9355.4-12)	25	U.S. EPA

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
141.	07/15/94	OPPTS/U.S. EPA	Memorandum re: Guidance on Residential Lead-Based Paint, Lead-Contaminated Dust and Lead-Contaminated Soil	32	U.S. EPA
142.	07/27/94	Brody, D., et al.	Journal Article: "Blood Lead Levels in the U.S. Population" (Journal of the American Medical Association)	7	
143.	07/27/94	Goldman, L. and Carra, J.	Editorial: "Childhood Lead Poisoning in 1994" (Journal of the American Medical Association)	2	
144.	07/27/94	Pirkle, J., et al.	Journal Article: "The Decline in Blood Lead Levels in the United States" (Journal of the American Medical Association)	8	
145.	10/14/94	A. Marcus, U.S. EPA	Preliminary Assessment of Data from the Madison County Lead Study and Implications for Remediation of Lead-Contaminated Soil	25	
146.	12/91	Var.	Journal Articles: "Chemical Speciation and Bioavailability" (Proceedings of the Symposium on the Bioavailability and Dietary Exposure of Lead Volume 3)	178	
147.	1990	Crocetti, A., et al.	Journal Article: "Determination of Numbers of Lead-Exposed Women of Childbearing Age and Pregnant Women: An Integrated Summary of a Report to the U.S Congress on Childhood Lead Poisoning" (Environ. Health Perspectives)	4	
148.	10/14/94	U.S. EPA	Proposed Plan NL Industries/Taracorp Superfund Site, Granite City, Illinois	6	
149.			Article: "Why Glass is a Good Host for Hazardous Waste"	4	
150.			Burdened Cost Breakdowns to Dispose of Non Hazardous Material Versus Leaving Material on Taracorp Stockpile	1	
151.			Graphs of Seven Additional Lots	7	
152.		IDPH	IDPH Standard Form for Obtaining Environmental Samples	1	
153.		B. Bradley, U.S. EPA	Letter re: U.S. EPA's Comments on the December 1992 Sampling Area Boundary Definition Study	1	G. Liu, USACE
154.		Wixson, B. and Davies, B., eds.	Report: "Society for Environmental Geochemistry and Health 'Lead in Soil' Task Force Recommended Guidelines" (DRAFT)	215	
155.		Foster Wheeler Enviresponse, Inc.	Report: "Selection of Control Technologies for Remediation of Lead Battery Recycling Sites"	141	U.S. EPA

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
156.		U.S. EPA	Article: "Technology to Clean and Separate Sodium Battery Casing on Site" (Superfund Report)	1	
157.		U.S. EPA	U.S. EPA/ 5 Dust Sample Preparation Flow Chart	4	File
158.	12/31/12	National Lead Company	Annual Report for the Fiscal Year Ending December 31, 1912	12	
159.	1985	American Society for Metals	Excerpts from: "Selected Properties of Pure Metals" (Metals Handbook)	3	
160.	1988	U.S. EPA	Table: Summary of Lowest Observed Effect Levels for Lead Induced Health Effects in Children and Adults	4	
161.	1991	Mushak, P.	Article: "Gastro-Intestinal Absorption of Lead in Children and Adults: Overview of Biological and Biophysico-Chemical Aspects" (Chemical Speciation and Bioavailability)	18	
162.	04/09/90	J. Clark, U.S. EPA	Telephone Record re: Lead Reduction in Soil from Use of Lime or Phosphate	3	W. Buck, University of Illinois
163.	04/20/90	U.S. EPA	Article: "EPA Draft Lead Pollution Plan Calls for Tougher Air Emissions Laws" (Inside EPA Weekly Report)	6	
164.	06/90	Syracuse Research Corporation	Toxicological Profile for Lead	207	U.S.EPA/US DHHS/USPHS/ATSDR
165.	06/21/90	U.S. EPA/OSWER	Memorandum re: Cleanup Level for Lead in Groundwater	4	P. Tobin, U.S. EPA
166.	06/27/90	U.S. EPA	Site Contingency Measures Calculations	1	File
167.	09/26/90	S. Siegel, U.S. EPA	Letter re: Revised Generator Waste-In List w/Updated Information on Several PRPs	18	D. Reis, Sidley & Austin
168.	10/17/90 and 11/16/90	G. Haskins, Bechtel	Letters re: Proposed Omission of Tilling Discing From the Ruston / Tacoma RI/FS	5	M. Voytilla, U.S. EPA

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
169.	12/09/90	M. Voytilla, U.S. EPA	Memorandum re: Point of Compliance for Residential Soils Cleanup at Ruston / North Tacoma Superfund Site	13	S. Cange, and J. Tieger, U.S. EPA
170.	12/13/90	G. Curtis, U.S. EPA	Memorandum re: Meeting Notes for the November 26, 1990 Kansas / Missouri Health Studies Meeting	5	Var.
171.	1991	Nilsson, U., et al.	Article: "Kinetics of Lead in Bone and Blood after End of Occupational Exposure" (Pharmacology and Toxicology)	8	
172.	02/12/91	B. Kelcher, U.S. EPA	Memorandum re: Cleanup Levels for Lead Contaminated Soils	6	J. Rosenbloom, U.S. EPA
173.	02/25/91	L. Pabinski, ATSDR	Memorandum re: Blood Studies w/Attachment	4	B. Kush, U.S. EPA
174.	03/13/91	L. Pabinski, ATSDR	Memorandum re: Multistate Lead Exposure Study Pending for Environmental Sampling	2	D. Ullrich, U.S. EPA
175.	03/26/91	M. Royer, U.S. EPA/ORD	Letter Forwarding Attached Marketing Studies Report for Lead Acid Battery Residuals at Gould Site: Portland, OR	294	A. Bossman, U.S. EPA
176.	03/26/91	USACE	Memorandum re: Superfund Project Management Acquisition Strategy	7	File
177.	04/91	U.S. EPA/OSW ER/ORD	Superfund Engineering Issue Bulletin: "Treatment of Lead Contaminated Soils"	10	
178.	04/29/91	D. Ullrich, U.S. EPA	Letter re: Consistency Between Studies in 5 and 7 (UNSIGNED)	1	D. Wagoner, U.S. EPA
179.	05/91	CH2M Hill	Report: "Final House Dust Remediation Report for the Bunker Hill CERCLA Site Populated Areas" RI/FS	11	Idaho Department of Health and Welfare
180.	05/03/91	S. Baer, IEPA	Memorandum re: Meeting at University of Illinois College of Medicine Concerning UI's Proposed Study at NL Industries/Taracorp Site	70	File
181.	05/07/91	S. Campolucci	Letter re: The University of Illinois as Contractors	1	H. Cascell, ATSDR

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
182.	05/23/91	Henke, B. and Tarpoff, C.	Paper: "N.L. Taracorp Superfund Site Lead Clean Up: A Justifiable Approach" (25th Conference on Trace Substances in Environmental Health)	56	
183.	05/30/91	P. Van Leeuwen, U.S. EPA	Memorandum re: Review of the Final Draft Quality Assurance Project Plan for the U.S. EPA 7 Support of the ATSDR Multistate Lead Exposure Study	5	G. Curtis, U.S. EPA
184.	06/01/91	S. Beer, IEPA	Letter re: IEPA's Comments on the Draft Scope of Services	2	B. Bradley, U.S. EPA
185.	06/24/91	S. Baer, IEPA	Letter re: Use of Stainless Steel During Monitoring Well Construction	1	B. Bradley, U.S. EPA
186.	06/27/91	IDPH	Fact Sheet: "Granite City Heavy Metal Exposure Study"	2	
187.	07/01/91	P. Mushak,	Independent Scientific Review of: (1) the ROD w/Appendices A and B; (2) NLI's Response to the ROD; (3) Relevant Data From the RI/FS; and (4) the IEPA's 1982 Blood Lead Study	10	A. Held, U.S. DOJ; S. Siegel, and R. Elias, U.S. EPA
188.	07/08/91	R. Kimbrough, IEHR	Letter re: the Start of Health Studies in Madison County	2	B. Bradley, U.S. EPA
189.	07/15/91	Waldman, S.	Journal Article: "Lead and Your Kids" (Newsweek)	18	
190.	07/15/91	P. Van Leeuwen, U.S. EPA	Letter re: U.S. EPA's Comments on the ATSDR Multistate Lead Exposure Study	4	J. Lybarger, USDHHS/USPHS/ATSDR
191.	07/16/91	Hydrometrics, Inc.	Report: "Work Plan for Excavation and Removal of Residential Soils: East Helena, Montana"	109	ASARCO Inc.
192.	07/22/91	S. Baer, IEPA	Letter re: Excavations at the St. Louis Recyclers Facility w/Attachment	2	B. Bradley, U.S. EPA
193.	07/23/91	S. Baer, IEPA	Letter re: Agency Contacts	4	T. Long, IDPH
194.	07/24/91	P. Van Leeuwen, U.S. EPA	Memorandum re: Review of the Final Draft Quality Assurance Project Plan for the U.S. EPA 7 Support of the ATSDR Multistate Lead Exposure Study	2	G. Curtis, U.S. EPA

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
195.	08/01/91	B. Bradley, U.S. EPA	Letter re: Access Agreements	1	S. Bacon, Granite City/Office of the Mayor
196.	08/13/91	R. Kimbrough, IEHR	Memorandum re: Environmental Sampling in Madison County	5	P. Van Leeuwen, U.S. EPA
197.	08/21/91	P. Van Leeuwen, U.S. EPA	Memorandum re: Environmental Sampling Protocols for the ATSDR Tri State Environmental / Blood Metal Study	2	B. Bradley, U.S. EPA
198.	08/22/91	K. Hagg, Woodward-Clyde	Cover Letter Transmitting the Chemical Data Acquisition Plan	1	B. Bradley, U.S. EPA
199.	08/28/91	D. Ullrich, U.S. EPA	Memorandum re: Analytical Support for the Multistate Lead Exposure	2	P. Reed, U.S. EPA
200.	08/29/91	R. Elias, U.S EPA	Memorandum re: Dust and Drinking Water Sampling Protocols for Pb Exposure	2	P. Van Leeuwen, U.S. EPA
201.	09/91	IDPH	IDPH Lead Exposure Study Participant Consent Form	2	
202.	09/91	R. Peterson, USACE	Letter Forwarding Attached Final Scope of Services Report	122	B. Bradley, U.S. EPA
203.	09/11/91	U.S. EPA	Quality Assurance Project Plan for U.S. EPA / 7 Support of the ATSDR Multistate Lead Exposure Study	15	
204.	09/12/91	U.S. District Court for the Dist. of Mass.	Carmen Santiago v. The Sherwin Williams Company: Affidavit of Howard Mielke	24	
205.	09/18/91	U.S. EPA	Quality Assurance Project Plan for U.S. EPA / 5 Support of the ATSDR Multistate Lead Exposure Study	22	
206.	09/19/91	J. Lybarger, ATSDR	Letter re: the Attached FAX Transmission From a IDPH Contractor Concerning the Lead Study	5	T. Long, IDPH

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
207.	09/22/91	B. Bradley U.S. EPA and S. Baer, IEPA	Letter re: U.S. EPA/IEPA's Comments on the Draft Chemical Data Acquisition Plan	12	T. Buchholz, USACE
208.	10/91	Woodward-Clyde	Chemical Data Acquisition Plan w/Appendices and Site Safety and Health Plan	683	USACE
209.	10/04/91	B. Hanke, City of Granite City	Letter re: Granite City's Concern About Groundwater and Soil Contamination Under and Around the Pile	3	B. Bradley, U.S. EPA
210.	10/09/91	T. Buchholz, USACE	Letter re: USACOE's Comments on the Chemical Data Acquisition Plan and the Architect Engineer Site and Safety Health Plan	12	K. Hagg, Woodward-Clyde
211.	10/15/91	T. Long, IDPH	Letter re: Soil Tilling Project w/Attached September 24, 1991 "Statement of Work: Soil Homogenization Pilot Study"	150	C. Tarpoff, Granite City Citizen Advisory Panel
212.	10/21/91	D. Ullrich, U.S. EPA	Letter re: Completion of Environmental Sampling	2	W. Adams, USDHHS/US PHS, ATSDR
213.	11/04/91	T. Fitzgerald, IEPA	Letter re: IEPA's Points of Concern on the Draft Chemical Data Acquisition Plan	3	B. Bradley, U.S. EPA
214.	12/03/91	MRI	ATSDR Lead and Cadmium Exposure Studies Debriefing	18	USDHHS/US PHS/ATSDR
215.	12/13/91	T. Fitzgerald, IEPA	Letter re: IEPA's Comments on the Chemical Data Acquisition Plan	17	B. Bradley, U.S. EPA
216.	01/17/92	D. Payne, U.S. EPA	Handwritten Memorandum re: Soils Data for Cd and Pb Field Duplicates	1	B. Bradley, U.S. EPA

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
217.	02/07/92	D. Klatt, Ecology and Environment, Inc.	Letter Forwarding Attached Analytical Data Tables for Priority and Priority Duplicate Samples	7	B. Bradley, U.S. EPA
218.	02/07/92	U.S. EPA	Request for Special Analytical Services Under the Contract Laboratory Program (ICP)	13	
219.	02/07/92	U.S. EPA	Request for Special Analytical Services Under the Contract Laboratory Program (GFAA)	13	
220.	02/20/92	S. Siegel, U.S. EPA	Letter re: U.S. EPA's Cleanup Plans	2	J. Gajewski, Madison Resident
221.	03/10/92	S. Carlock, USACE	Letter re: USACOE's Request for Comments on the Proposed Evaluation Method for Lead Concentrations in the Residential Areas	1	B. Bradley, U.S. EPA
222.	04/07/92	D. Payne, U.S. EPA	Memorandum re: ATSDR Study Soils and Drinking Water Data for Granite City	2	B. Bradley, U.S. EPA
223.	04/07/92	D. Payne, U.S. EPA	Memorandum re: Analysis Procedures for Cadmium and Lead in Dust at Granite City	2	B. Bradley, U.S. EPA
224.	04/08/92	D. Vornberg, Doe Run Company	Letter re: Possibility of Recovering the Metal Value From the Slag Pile	3	B. Bradley, U.S. EPA
225.	04/16/92	D. Klatt, Ecology and Environment, Inc.	Letter Forwarding Attached Analytical Data Tables for Field and Duplicate Samples	24	B. Bradley, U.S. EPA
226.	04/20/92	J. Rademacher, PR & Associates	Letter Forwarding Attached Statement of Qualification From Solids Management, Inc. w/Additional Attachments	28	B. Bradley, U.S. EPA
227.	05/92	U.S. EPA/ORD	Applications Analysis Report: "Horsehead Resource Development Company Inc. Flame Reactor Technology" (EPA/540/A5-91/005)	73	U.S. EPA

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
228.	05/01/92	R. Guimond, U.S. EPA/HQ	Letter re: The Bunker Hill Success Story	4	R. Smith, U.S. EPA
229.	05/15/92	U.S. EPA	Inside EPA Article: "EPA Recommends Innovative Superfund Cleanup Based on Recycling Waste"	1	
230.	06/02/92	D. Payne, U.S. EPA	Handwritten Memorandum re: ATSDR Study Split Sample Analysis for Lead in Drinking Water	7	B. Bradley, U.S. EPA
231.	06/07/92	D. Payne, U.S. EPA	Handwritten Memorandum re: ATSDR Study Comparison of Lead Results for First 59 Soil Samples Tested for Granite City	4	B. Bradley, U.S. EPA
232.	06/12/92	J. Bennett, City of Aspen	Letter re: the Formation of the Smuggler Mountain Site Technical Advisory Committee	7	B. Pinkowski, U.S. EPA
233.	06/18/92	D. Payne, U.S. EPA	Handwritten Memorandum re: ATSDR Study Split Sample Comparative Analysis for Lead in Drinking Water	9	B. Bradley, U.S. EPA
234.	06/22/92	D. Payne, U.S. EPA	Handwritten Memorandum re: ATSDR Study Lead Results for Soils	5	B. Bradley, U.S. EPA
235.	06/22/92	C. Klatt, Ecology and Environment, Inc.	Letter Forwarding Attached Tables for Field Samples and Field Duplicate Samples	24	B. Bradley, U.S. EPA
236.	07/10/92	Woodward-Clyde	Residential Soil Lead Sampling	15	
237.	07/17/92	B. Johnson, and H. Cassell, ATSDR	Letter re: Premature Public Disclosure the IDPH's Study Results and Conclusions	2	J. Lumpkin, IDPH
238.	07/24/92	J. Lumpkin, IDPH	Letter Responding to ATSDR's July 17, 1992 Letter re: Premature Public Disclosure of the IDPH's Study Results and Conclusions	2	B. Johnson, ATSDR

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
239.	08/10/92	D. Klatt, Ecology and Environment, Inc.	Letter Forwarding Attached Additional Dust Sampling Data	19	B. Bradley, U.S. EPA
240.	08/21/92	Ecology and Environment, Inc.	Environmental Sampling Project (ATSDR Multi State Lead Exposure Study): Sampling Summary and Analytical Data Report w/Cover Letter	77	U.S. EPA
241.	08/25/92	S. Carlock, USACE	Letter re: USACOE's Comments to IEPA's on the Chemical Data Acquisition Plan	31	B. Bradley, U.S. EPA
242.	09/92	Information Systems Solutions International, Inc.	Summary of the Presentation Notes From the Symposium on Urban Soil Lead Abatement	19	U.S. EPA/OERR
243.	09/30/92	ATSDR	Lead Initiative Summary Report	10	U.S. EPA
244.	10/92	U.S. EPA/OSWER	Quick Reference Fact Sheet: "Three City Urban Soil Lead Abatement Demonstration Project" (Publication #9355.4-10FS2)	5	U.S. EPA
245.	10/92	U.S. EPA/OSWER/ORD	Technical Guidance Document: "Construction Quality Management for Remedial Action and Remedial Design Waste Containment Systems" (EPA/540/r-92/073)	102	U.S. EPA
246.	10/09/92	D. Payne, U.S. EPA	Letter re: Analytical Procedures for Cadmium and Lead in Dust at Granite City w/Attachments	7	D. Webb, IDPH
247.	10/28/92	Smuggler Mountain Site Technical Advisory Committee	Report of the TAC Meeting w/Attached Agenda	23	
248.	12/92	Woodward-Clyde	Sampling Area Boundary Definition Study	21	USACE
249.	01/05/93	IDPH	Blood Study Map	1	U.S. EPA

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
250.	03/93	Woodward-Clyde	Final Report	239	U.S. EPA
251.	03/93	Woodward-Clyde	Final Report: Appendix A (Volume 1)	555	U.S. EPA
252.	03/93	Woodward-Clyde	Final Report: Appendix A (Volume 2)	329	U.S. EPA
253.	03/93	Woodward-Clyde	Final Report: Appendix B	276	U.S. EPA
254.	03/93	Woodward-Clyde	Final Report: Appendix C, D, and E	253	U.S. EPA
255.	03/93	Woodward-Clyde	Final Report: Appendix F (Volume 1)	516	U.S. EPA
256.	03/93	Woodward-Clyde	Final Report: Appendix F (Volume 2)	299	U.S. EPA
257.	03/93	Woodward-Clyde	Final Report: Appendix G	644	U.S. EPA
258.	03/93	Woodward-Clyde	Final Report: Appendix H, I, and J	313	U.S. EPA
259.	03/93	Woodward-Clyde	Final Report: Appendix K (Volume 1)	737	U.S. EPA
260.	03/93	Woodward-Clyde	Final Report: Appendix K (Volume 2)	731	U.S. EPA
261.	03/93	Woodward-Clyde	Final Report: Appendix L, M, and N	445	U.S. EPA
262.	03/93	Woodward-Clyde	Final Report: Attachments and Addendum	259	U.S. EPA
263.	03/02/93	B. Colman, IEPA	Letter re: IEPA's Comments on the Explanation of Significant Differences	2	B. Bradley, U.S. EPA

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
264.	03/26/93	C. Tarpoff, Citizens Advisory Committee	Letter re: Use of Dust Detection Equipment	2	T. Long, IDPH
265.	03/29/93	S. Carlock, USACE	Final Pre Design Field Investigation Final Report	226	B. Bradley, U.S. EPA
266.	03/31/93	T. Long, IDPH	Letter re: Lead Dust During Remedial Action	1	C. Tarpoff, City of Granite City
267.	03/31/93	T. Long, IDPH	Letter re: Request for Additional Real Time Dust Monitoring	4	B. Bradley, U.S. EPA
268.	04/93	Woodward-Clyde	Supplemental Groundwater Investigation: Third Round of Groundwater Sampling	70	USACE
269.	05/07/93	W. Muno, and G. Ginsberg, U.S. EPA	Memorandum re: Request for Concurrence on the Explanation of Significant Differences for the Remedial Action	11	V. Adamkus, U.S. EPA
270.	05/11/93	L. Train, EPS Environmental, Inc.	Letter Forwarding Attached Overview of EPS Environmental	9	B. Bradley, U.S. EPA
271.	06/17/93	J. Traub, U.S. EPA	Letter re: U.S. EPA's Request that ATSDR Provide Specific Biological and Other Data	3	J. Lybarger, USDHHS/USPHS/ATSDR
272.	08/23/93	Environmental Chemical Corporation	Analytical Results and Site Maps of Lots	90	OHM
273.	09/01/93	K. Hagg, Woodward-Clyde	Site Safety and Health Plan: Addendum #3	2	
274.	09/03/93	OHM	Health and Safety Project Summary: Rapid Response Lead Contamination Remediation	57	USACE

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
275.	09/03/93	J. Habegger, OHM	Letter re: Precharacterization Sampling of 21 Additional Sites	23	B. Bradley, U.S. EPA
276.	09/15/93	S. Thomas, Doe Run Company	Letter re: Doe Run's Request to Obtain a Five Hundred Ton Sample	1	B. Bradley, U.S. EPA
277.	09/15/93	B. Bradley, U.S. EPA	Letter re: U.S. EPA's Comments on the Addendum to the PFDI Chemical Data Acquisition Plan for Supplemental Investigations	4	G. Lin, USACE
278.	09/23/93	S. Holt, NL Industries, Inc.	Letter re: the Application of "Coherex" to the Taracorp Waste Pile	2	B. Bradley, U.S. EPA and B. Colman, IEPA
279.	09/28/93	G. Webb, Taracorp Industries, Inc.	Letter re: Fenceline Repair	1	B. Bradley, U.S. EPA
280.	10/93	B. Bradley, U.S. EPA	Letter re: Clarification of U.S. EPA's October 1, 1993 Letter Concerning the Collection of a Waste Sample from the Taracorp Pile	1	S. Thomas, Doe Run Company
281.	10/01/93	B. Bradley, U.S. EPA	Letter re: the Collection of a Sample from the Taracorp Pile	2	S. Thomas, Doe Run Company
282.	10/05/93	Woodward-Clyde	Amended Final Chemical Data Acquisition Plan and Site Safety Health Plan w/Cover Letter	125	U.S. EPA
283.	11/93	Woodward-Clyde	Supplemental Groundwater Investigation: Fourth Groundwater Sampling Event	94	U.S. EPA
284.	11/02/93	J. Garcia, and C. Pavelka, Woodward-Clyde	Letter re: Petroleum Hydrocarbons Soil Contamination	2	G. Lin, USACE

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
285.	11/09/93	R. Robertson, Granite City Park District	Letter re: Excavation, Removal, and Replacement of Land at the Lincoln Place Community Center	2	K. Holowinski, U.S. DOJ and S. Siegel, U.S. EPA
286.	11/09/93	B. Bradley, U.S. EPA	Letter re: Inspection of Taracorp Pile	3	S. Holt, NL Industries, Inc.
287.	11/09/93	E. Fitzhenry, City of Granite City	Letter re: Remediation Activities	2	K. Holowinski, U.S. DOJ
288.	11/09/93	PRC Environmental Management, Inc.	Revised Community Relations Plan	30	U.S. EPA
289.	11/15/93	B. Bradley, U.S. EPA	Memorandum re: the Paving of Alleys and Driveways at the NL Industries Site	1	File
290.	11/17/93	E. Fitzhenry, City of Granite City	Letter re: Remediation Activities	1	K. Holowinski, U.S. DOJ
291.	11/17/93	B. Bradley, U.S. EPA	Letter re: U.S. EPA's Request for IDPH's Assistance in Performing Assessments at Residences	3	T. Long, IDPH
292.	11/29/93	OHM	Final Contractor's Sampling and Analysis Plan for Remediation	132	USACE
293.	12/01/93	OHM	Analytical Results for 1406 State	1	B. Bradley, U.S. EPA
294.	12/01/93	B. Bradley, U.S. EPA	Letter re: U.S. EPA's Approval of (1) the Addendum to the Pre Design Field Investigation; (2) the Chemical Data Acquisition Plan; and (3) the Site Safety Health Plan for Supplemental Investigations	1	G. Lin, USACE

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
295.	12/03/93	C. Pavelka, and D. Pate, Woodward-Clyde	Letter re: Residential Properties with Soil Lead Concentrations Above 1,500 PPM w/Attachment	3	B. Bradley, U.S. EPA
296.	12/07/93	OHM	Soil Sample Results	2	B. Bradley, U.S. EPA
297.	12/15/93	B. Colman, IEPA	Letter re: IEPA's Comments on the Explanation of Significant Differences	12	B. Bradley, U.S. EPA
298.	12/17/93	B. Colman, IEPA	Letter re: IEPA's Comments on the Draft Final Work Plan for Stabilization of Hazardous Wastes w/Attachments	4	B. Bradley, U.S. EPA
299.	12/29/93	B. Bradley, U.S. EPA	Memorandum re: On Site Solidification of RCRA Hazardous Battery Case Material	2	File
300.	01/94	USACE	PFDI Supplemental Investigation: Remote Fill Areas Analytical Data Summary	78	U.S. EPA
301.	01/06/94	USACE and Woodward-Clyde	PFDI Supplemental Investigation Report: Remote Fill Areas Analytical Data Summary w/Cover Letter	53	U.S. EPA
302.	01/13/94	B. Bradley, U.S. EPA	Letter re: Additional Properties for Soil Cleanup	2	T. Long, IDPH
303.	01/21/94	E. Fitzhenry, City of Granite City	Letter re: Remediation Activities	1	B. Bradley, U.S. EPA
304.	01/27/94	B. Bradley, U.S. EPA	Handwritten Letter re: U.S. EPA's Review Comments on the Draft Scope of Work (HANDWRITTEN)	2	A. Kam, USACE
305.	01/27/94	B. Bradley, U.S. EPA	Letter re: U.S. EPA's Approval of the Remote Fill Areas Analytical Data Summary Report	2	G. Lin, USACE
306.			Videos of the Site		

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
307.	01/27/94	W. Manno, and G. Ginsberg, U.S. EPA	Memorandum re: Request for Concurrence on the Explanation of Significant Differences for the Remedial Action	17	V. Adamkus, U.S. EPA
308.	01/28/94	OHM	Addendum #1 to the Final Amended Work Plan for Stabilization of Hazardous Waste for Sampling, Stabilization, and Analysis for Illinois State Acceptance Certificate	39	USACE
309.	02/02/94	J. Hitchings, OHM	Letter Transmitting Attached Revisions to the January 10, 1994 Final Amended Work Plan for Stabilization of Hazardous Wastes	48	USACE
310.	02/03/94	B. Colman, IEPA	Letter re: IEPA's Comments on the Final Amended Work Plan for the Stabilization Project	1	B. Bradley, U.S. EPA
311.	02/04/94	OHM	Drawing: Containment System Plan and Details	8	
312.	02/07/94	Sevenson Environmental Services, Inc.	1993 Annual Report	32	
313.	02/14/94	R. Oslan, Kirkland & Ellis	NLI's Response to 104(e) Information Request	90	S. Siegel, U.S. EPA
314.	02/28/94	A. Wohl, LADHH	Final Report: "The Impact of a Los Angeles County Stationary Lead Source on the Blood Lead Levels of Children Living Nearby"	68	J. Semonce, U.S. EPA
315.	04/22/94	E. Page, Woodward-Clyde	*Letter w/Attached Notes of April 21, 1994, IDPH Public Meeting on Blood Levels in Children*	8	B. Bradley, U.S. EPA
316.	05/10/94	K. Yost,	Paper: "Lead and Other Heavy Metal Fixation in Soils and Solid Waste by the Maectite Chemical Treatment Process" (Purdue Industrial Waste Conference)	20	
317.	06/07/94	Chemtex	Analytical Results	35	OHM
318.	06/08/94	D. Moore, Kirkland & Ellis	Letter Forwarding Attached Exhibits #7 and #8 to the Charles Sparks Deposition	4	S. Siegel, U.S. EPA
319.	06/23/94	OHM	Final Revised Scope of Work for Stack Emissions (Lead) Removal Report	213	

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
320.	07/15/94	B. Culnan, IEPA	Letter re: IEPA's Response to U.S. EPA's Request to Evaluate a Proposal for the Treatment of a 100 200 Ton Sample from the Slag Pile	1	B. Bradley, U.S. EPA
321.	07/21/94	OHM	Sampling Data Sheets: Monitoring Data for Most Locations During Phase III: April July, 1994	92	
322.	08/94	USACP	First Quarter 1994 Groundwater Sampling Event	131	U.S. EPA
323.	08/09/94	Chemtex	Employee Exposure Monitoring Log Sheets-Lead	130	
324.	08/09/94	USACE	Perimeter Air Sampling Log-Lead	128	
325.	08/09/94	OHM	Sampling Data Sheets: Air Monitoring for Stack Emission Sites From August 9, 1994 to the Present	189	
326.	08/10/94	Environmental Chemical Corporation	Soil Sample Results	4	OHM
327.	08/16/94	B. Bradley, U.S. EPA	Letter re: Results of Additional Soil Samples from the Park at 1201 Washington (HANDWRITTEN)	1	J. Belloff, City of Madison
328.	09/09/94	OHM	Stabilization Pilot Scale Testing Report for Lead Contaminated Slag Mound Material From NL Industries / Taracorp Site w/Attached Order of Magnitude Estimate	16	B. Bradley, U.S. EPA
329.	09/15/94	Granite City Residents	Petition: "Stop Granite City Lawsuit Against U.S. EPA"	8	U.S. EPA
330.	10/94	U.S. EPA	Fact Sheet: "Proposed Plan"	6	Public
331.	10/10/94	A. Rao, and C. Reddy, Chemtex	Analytical Results	5	T. Soom, and S. Blassingame, OHM
332.	10/21/94	A. Davis, U.S. EPA	Memorandum re: Dallas Area Intergovernmental Steering Committee for Lead Issues w/Attachments	6	E. Laws, U.S.EPA
333.	10/25/94	Woodward-Clyde	FAX Transmittal: October 14, 1994 Sampling Plan for NL / Taracorp Waste Pile	4	U.S. EPA
334.	10/27/94	L. Harrington, U.S. EPA	Letter re: Doe Run's Ability to Accept Wastes From CERCLA Sites (UNSIGNED)	2	D. Vornberg, Doe Run Company
335.	11/09/94	C. McPheeters, Sevenson Environmental Services, Inc.	Letter Forwarding Attached December 1993 "Maectite Treatment Process: Lead and Other Heavy Metal Fixation Technical Information Bulletin"	72	B. Bradley, U.S. EPA

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
336.	12/05/94	S. Mulroney, U.S. EPA	Letter re: U.S. EPA's Approval of Granite City's Request for an Extension to the Public Comment Period	1	E. Fitzhenry, City of Granite City
337.	12/14/94	U.S. EPA	Public Notice re: "Extension of the Public Comment Period" (Granite City Journal)	1	Public
338.	12/15/94	U.S. EPA	Public Notice re: "Extension to the Public Comment Period" (Granite City Press Record)	1	Public
339.	01/95	Freshwater Foundation	Journal Article: "Sources of Lead Exposure in Granite City, Illinois" (Health & Environment Digest)	3	
340.	01/95	W. Stephens, RMT, Inc.	Letter re: Treatment of Heavy Metals at Remediation Sites w/Attached "RMT Metals Remediation Technologies" Brochure	10	B. Bradley, U.S. EPA
341.	02/95	U.S. EPA	Proposed Plan	10	Public
342.	02/95	USACE	Second Addendum to the FS w/Attached Correspondence	200	U.S. EPA
343.	02/95	USACE	Waste Pile Investigation Report	45	U.S. EPA
344.	02/08/95	U.S. EPA	News Release Announcing March 6, 1995 Public Meeting re: Public Comments on the Proposed Plan	2	Public
345.	02/09/95	D. Vornberg, Doe Run Company	Letter re: Recycling of Granite City Slag Pile	1	B. Bradley, U.S. EPA
346.	02/09/95	S. Bianchin, U.S. EPA	Telephone Discussion w/D. Vornberg (Doe Run Company) re: Economics, Available Technology, and Regulatory Status Concerning Doe Run's Ability to Accept the NL / Taracorp Waste Pile	2	File
347.	02/25/95	S. Mulroney, U.S. EPA	Letter re: U.S. EPA's Denial of Granite City's Request for an Extension to the Public Comment Period	1	E. Fitzhenry, City of Granite City
348.	03/02/95	W. Dickett, Sidley & Austin	Letter re: Johnson Controls Request for an Extension to the Proposed Plan Public Comment Period	1	S. Pastor, and B. Bradley, U.S. EPA
349.	1995	R. Renner	Journal Article: "When Is Lead A Health Risk" (Environmental, Science & Technology)	6	
350.	08/01/95	L. Bonacorsi, J. Nassif and D. Reis	Letter re: Request by the PRPs for the attached documents to be included in the Administrative Record	71	S. Pastor, U.S. EPA
351.	09/21/94		Transcript of Court Hearing	26	
352.	11/18/94	DHHS	Grant package between ATSDR and IDPH for the "Lead Exposure Study"	295	

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
353.	02/07/95	U.S. Experts	Consensus Statements: Ad Hoc Expert Committee on Lead Contamination in the Madison County/Granite City Area	6	
354.	08/16/95	S. Mulroney, U.S. EPA	Letter re: EPA's request for the City to provide documentation and/or data to their Comments submitted during the most recent public comment periods	1	E. Fitzhenry, Granite City
355.	04/95	IDPH	Final Report: Madison County Lead Exposure Study	278	
356.	10/25/94		Transcript of Public Meeting re: 500 PPM	81	
357.	10/26/94		Transcript of Public Meeting re: 500 PPM	99	
358.	08/06/95		Transcript of Public Meeting re: Groundwater/Pile	72	
359.	Fall/95	W. Hunsperger	Journal Articles: "Heavy Metal Pollution And Residential Property Damages" and "Appraisal Guidelines And Mortgage Policies Considered Under Lead Paint Act" (Appraisal Institute/Environmental Watch)	6	
360.	07/95		Magazine Articles: "Safe at Home"; "Lead in Paint: Controlling the Hazard"; "Lead in Paint: Test Kits"; and "Lead in Water" (Consumer Reports)	7	
361.	07/95	U.S. EPA	Report re: "Contaminants and Remedial Options at Selected Metal-Contaminated Sites"	258	
362.	08/17/95		Cost Update for Remote Fill Areas	1	
363.	09/06/95	OHM	Truck Lot Sampling Data	1	
364.		DOT	Average Daily Traffic Counts in the Granite City Area	88	
365.	01/11/95	E. Fitzhenry, Granite City	Granite City Comments on the Clean-up Level with attachments	288	S. Pastor, U.S. EPA
366.	01/13/95	Var.	Certain PRP Comments on the Clean-up Level with attachments	826	S. Pastor, U.S. EPA
367.	04/17/95	V. Kramer, G. Shikaze and N. Valkenburg	Report: "Review and Comments on the USEPA Proposed Groundwater Remedy for the NL Industries/Taracorp Superfund Site, Granite City, IL" (Geraghty & Miller, Inc.)	63	
368.	04/18/95	Var.	Letter re: PRP Comments on the Groundwater/Pile	3	S. Pastor, U.S. EPA
369.		Public	Public Comments on Clean-up Level	28	U.S. EPA
370.		Public	Public Comments on Groundwater/Pile	17	U.S. EPA
371.	08/05/94		Site Safety and Health Plan	11	

A.R. DOC.#	DATE	AUTHOR	TITLE/DESCRIPTION	PAGES	RECIPIENT
372.	11/29/93	OHM	Final Contractor's Sampling and Analysis Plan	164	
373.	10/10/94	OHM	Draft Work Plan for Remediation of Locations in Granite City, Madison, and Venice, Illinois, Associated with NL Industries/Taracorp Superfund Site	345	USACE
374.	05/16/95	OHM	Draft/Amended Work Plan for Stabilization of Hazardous Waste in Granite City, Madison, and Venice, Illinois, Associated with NL Industries/Taracorp Superfund Site	131	USACE
375.	01/18/95	C. Tapoff	Comments Regarding the Lead Clean-up Level	5	
376.	04/20/95	C. Tapoff	Comments Regarding File	4	S. Pastor, U.S. EPA
377.	09/29/95	U.S. EPA	DD/ESD with attachments	333	

ATTACHMENT 2

NL INDUSTRIES/ TARACORP
GRANITE CITY, ILLINOIS
RESPONSIVENESS SUMMARY REGARDING RESIDENTIAL SOIL CLEANUP

I. RESPONSIVENESS SUMMARY OVERVIEW

In 1985, NL Industries, Inc. entered into an Agreement and Administrative Order by Consent with U.S. EPA and the State of Illinois. Under the terms of that consent order, NL was required, among other things, to conduct a remedial investigation ("RI") and feasibility study ("FS") for the Site. See Consent Order (AR No. 5), RI Report (AR No. 37), and FS Report (AR No. 151 and AR No. 152). The Site was subsequently placed on the National Priorities List ("NPL"), 40 C.F.R. Part 300, Appendix B. See 51 Fed. Reg. 21054 (June 10, 1986).

The RI revealed that operations at the Site contributed to extensive contamination of the soil, the air, and the threat of contamination of groundwater. Samples taken at the Site revealed high concentrations of lead in the soils and battery case material in the residential areas of the Site. The waste piles in the Site's industrial areas contain elevated concentrations of lead, antimony, arsenic, barium, cadmium, chromium, mercury, nickel, and zinc. The primary contaminant, lead, as well as the other metals, resulted primarily from the battery reclamation and smelting operations.

The FS and the FS addendum identify that hazardous substances at the Site have migrated and may continue to migrate through the air in the form of airborne emissions of dust. This presents certain pathways for exposure to hazardous substances by the resident population at the Site, including inhalation of airborne contaminants in the form of emissions and dust emanating from the waste piles, contaminated soils, and ingestion of soils, hard rubber fill from battery casing materials, or sediments.

At the time of the FS and FS addendum, U.S. EPA documented the accumulative poisonous nature of lead and that no known safe threshold level for lead exposure exists. Based on a full review of the Administrative Record, U.S. EPA reached a cleanup decision for the NL Site. The cleanup decision is embodied in the Record of Decision ("ROD"), which was signed by the Regional Administrator of U.S. EPA on March 30, 1990. Following unsuccessful efforts to negotiate a settlement under which PRPs would implement the remedy that U.S. EPA selected for the Site, U.S. EPA, on November 27, 1990, issued an administrative order, pursuant to Section 106 of CERCLA, 42 U.S.C. § 9606, directing certain PRPs to undertake the response actions identified in the ROD. In issuing this Order, U.S. EPA made a number of findings based on the administrative record for the Order before it, including a finding that the release and threat of release of hazardous substances from the facilities at the NL Site is or may be presenting an imminent and substantial endangerment to the public health or welfare or the environment.

None of the recipients of the Order notified U.S. EPA of its intention to comply fully with the Order. In view of the failure or refusal of PRPs to comply with the November 27, 1990, Administrative Order, U.S. EPA decided to use Superfund money to proceed with implementation of the remedy selected in the ROD.

On July 31, 1991, the United States commenced the United States v. NL Industries, Inc., et al. litigation, asserting claims against several PRPs: 1) to compel full compliance with U.S. EPA's Order; 2) for imposition of penalties and punitive damages for those PRPs' failure to comply with U.S. EPA's Order; and 3) to recover the response costs incurred and to be incurred by the United States at the Site.

At the suggestion of the Defendants, U.S. EPA agreed to reopen the administrative record to reevaluate the appropriate cleanup standard for lead in residential soils. Pursuant to that agreement, U.S. EPA held a public comment period from October 14, 1994 to January 13, 1995, to allow interested parties to comment on the selected residential soil cleanup level for lead at the Site. Public meetings were held at the Venice Senior Citizens Center, Venice, Illinois on October 25, 1994, and the Granite City Township Hall, Granite City, Illinois on October 26, 1994.

The purpose of this responsiveness summary is to document the Agency's responses to question, concerns, and comments received during the comment period and during the public hearing. These comments and concerns were evaluated prior to selection of the remedial action for the site.

A complete copy of the Administrative Record, and other pertinent information is available at the Granite City Public Library, Granite City, Illinois, and at the U.S. EPA office in Chicago, Illinois.

II. BACKGROUND ON COMMUNITY INVOLVEMENT

Community Relations Plan Summary

The Community Relations Plan (CRP) for the site was prepared by the U.S. EPA, which is responsible for community relations and remedial activities at the Site under CERCLA.

In general, there is concern about potential health risks caused by the Site, and specifically with lead contaminated soils in residential yards at the Site.

The U.S. EPA's community relations objectives are to:

- keep the community informed about the site,
- allow the community to have input into the decisions made to address lead contamination at Site.

Since its issuance of the Record of Decision for the Site in March 1990, U.S. EPA has issued numerous press releases and fact sheets to update the community regarding cleanup progress at the Site. Starting in 1991, U.S. EPA conducted several door-to-door access procurement activities, involving face-to-face visits with at least 400 residents in the cleanup zone.

Availability sessions were held in the spring of 1993 to kick off the cleanup of the battery case materials at the Site. In addition, a public meeting was held to solicit community input. Issues identified at the public meetings on October 25 and 26, 1994 are reflected in the transcript of the meetings and the replies are provided herein. This responsiveness summary responds to comments received during the public comment period for the residential soil cleanup level.

Community Concerns/Issues

The responsiveness summary have been divided into the following categories:

1. PUBLIC MEETING COMMENTS
2. WRITTEN GENERAL COMMENTS
3. WRITTEN TECHNICAL COMMENTS
4. WRITTEN HEALTH COMMENTS

The comments are paraphrased in order to effectively summarize them in this document. The reader can obtain the comments from the public and the written comments in their entirety by reviewing the administrative record, which is available at the Granite City Public Library, Granite City, Illinois and the offices of U.S. EPA, Region 5 located at 77 W. Jackson Blvd, Chicago Il, 7th floor.

PUBLIC MEETING COMMENTS

COMMENT P 1: Several commentors thought lead in soil was a major problem in the City. The commentors expressed concern that the IDPH health study had problems and criticized that the results were not given to the residents.

The commentors inform U.S. EPA that many families were aware of the lead problems for a long time before the blood study. For one year before the study, a very aggressive campaign was conducted by concerned citizens in the area to educate area citizens about the dangers of lead. Fliers were distributed which counselled parents not to let the child play in the dirt, to wash toys to keep the homes clean, and to give the children calcium, and offered lead screen~~ing.~~

The commentors expressed concern that if the City stops U.S. EPA from remediating the yards that parents will think its okay to let the children play in the yard. Furthermore, new residents may not be made aware of the dangers, that the property will continue to be under valued and "redlined" by the banks due to contaminated soil. The commentors felt that if the City of Granite City is successful in the law suit to stop the cleanup that the PRPs are the only winners. If a person wants his or her yard cleaned, they should have a right to have it done.

U.S. EPA RESPONSE TO COMMENT P 1:

U.S. EPA thanks the commentors for the information and agrees that persons have a right to have their yards remediated.

COMMENT P 2: One commentor wanted to know if EPA would be doing cleanups on the easements of the residential properties (i.e., the area between the street and the sidewalk). The commentor thought it would be a good idea if the entire property was cleaned at the same time.

U.S. EPA RESPONSE TO COMMENT P 2: To date, the City of Granite City has not allowed EPA to have access to those properties, except for the 17 properties which were agreed to by the City in the court settlement. Regarding the timing of the cleanup, EPA agrees with the commentor that it is more efficient if the easement is cleaned along with the rest of the property.

COMMENT P3. Comment: One commentor thanked EPA for fixing the street during the remedial process.

U.S. EPA RESPONSE TO COMMENT P 3: U.S. EPA appreciates the positive feedback on the restoration activities.

COMMENT P 4: One commentor wanted lead pipe and paint in his home removed.

U.S. EPA RESPONSE TO COMMENT P 4: EPA has no direct authority to remediate the interior of homes unless the contamination is caused by a release of contamination to the environment from the Superfund Site. Section 104 (a)(3)(B) of CERCLA states "the President shall not provide for a removal or remedial action under this section in response to a release or threat of release from products which are part of the structure of, and result in exposure within residential buildings. . . " Homeowners have the responsibility for the home interiors; however the local health department and HUD may be able to work with you for the lead pipe and the paint. U.S. EPA will attempt to work with HUD and the Illinois Department of Public Health to facilitate the interior paint remediation. In addition, U.S. EPA will make high efficiency vacuums available to the residents so that the lead dust in the house can be removed. Last, U.S. EPA can provide the commentor with a fact sheet that will outline ways to minimize exposures to lead in drinking water from lead pipe.

COMMENT P 5:

One commentor wanted the pile moved out of the City because it is an eyesore and the waste material in the pile should be sold or recycled.

U.S. EPA RESPONSE TO COMMENT P 5:

Refer to the response to comment 1 in the responsiveness summary for the Taracorp pile (Attachment 3).

COMMENT P 6:

One commentor who had his or her property already excavated praised U.S. EPA and its contractors for performing a professional and efficient job, and said that the cleanup was performed in the best possible manner. This commentor had witnessed U.S. EPA's remedial activities at numerous properties in the area and the commentor shared that U.S. EPA has worked efficiently, working on several homes at a time, using expert, professional and courteous employees to supervise the cleanup. The commentor pointed out that the residents living in that particular block are pleased and relieved that the excavation was being performed.

The commentor stated that it was helpful for U.S. EPA's contractors to work with the residents to make sure that there is a clean and safe entrance into the homes, and that all of the excavated dirt was covered at night to limit access from anyone.

The commentor also stated that he or she did not understand why the City of Granite City was fighting EPA in its effort to remediate lead, why the City would not grant access to EPA to clean the easements and mentioned that the City's motives appeared frivolous by expending monies to fight EPA instead of serving the citizenry and address the industries in the area which create serious dust and smoke problems, and felt that the citizens had a right to protect the health of their families and to improve the property values.

The commentor believed that the residential yards are the most important aspect to the remediation even before the pile since the pile is already controlled, and clearly stated "our biggest concern is or health, our children's health, and our property values".

U.S. EPA RESPONSE TO COMMENT P 6:

U.S. EPA thanks the commentor and agrees with these statements.

COMMENT P 7:

The commentor stated that he or she has a child living in the cleanup area and that there are other children living on the same block, and the primary concern is the children's health and safety.

The commentor felt that if new if new information comes to light with regard to a specific health hazards, such as the hazards from the lead, that the government should use the safest level rather than leaving it to a technical debate.

The commentor felt that the pile should be cleaned up before the yards to prevent recontamination.

U.S. EPA RESPONSE TO COMMENT P 7:

U.S. EPA thanks the commentor. Regarding the timing of the cleanup of the pile and yards, U.S. EPA is of the opinion that the yards pose a greater risk since individuals use the yards on a daily basis. Regarding the issue of recontamination, EPA has taken short term precautions to assure that dust from the pile does not blow off of it and EPA will take precautions in remediating the pile to minimize any dust; however, since the pile will be capped (See Comments in Attachment 3) most of the pile will not be physically moved, and recontamination of other properties is less of a concern.

EPA will attempt to proceed with remediating both the yards and the pile simultaneously; however the cap for the pile must still be designed.

COMMENT P 8:

The commentor stated that he or she has a child living in the cleanup area and that there are other children living on the same block, and the primary concern is the children's health and safety.

The commentor stated that he or she is primarily concerned with the yard excavation because the children play in the neighborhood yards everyday. The commentor stated that a majority of the people in the neighborhood wanted their yards cleaned. Regarding the pile, the commentor felt that it should be addressed; however, it was secondary. Commentor stated that the children could easily be kept away from the pile; however, it is more difficult to keep children out of the yards.

U.S. EPA RESPONSE TO COMMENT P 8:

U.S. EPA thanks the commentor and fully agrees with these statements.

COMMENT P 9:

The commentor stated that he or she agrees with the 500 ppm lead residential soil cleanup level and respected EPA as the experts in this area.

The commentor stated that he or she did not understand why the City of Granite City wants to stop the cleanup and the commentor was appalled that the City spent money fighting the cleanup where the money could be better spent elsewhere like fixing up the school.

U.S. EPA RESPONSE TO COMMENT P 9:

U.S. EPA thanks the commentor and appreciates the independent analysis of the situation.

COMMENT P 10:

The commentor agreed with EPA's proposed remedy and felt that it was of utmost importance to excavate the yards.
The commentor states that while lead paint is a problem throughout the United States, the lead in the yards is unique to Granite City.

The commentor requested that the Citizens Petition which was circulated in September 1994 be included in the Record.

U.S. EPA RESPONSE TO COMMENT P 10:

The U.S. EPA thanks the commentor and agrees to include the Petition in the Record.

WRITTEN GENERAL COMMENTS

COMMENT G 1. Several commentors stated that they agreed with EPA's residential cleanup program. One commentor presented a brief report which recommended that U.S. EPA choose 500 ppm for the lead in the residential soil cleanup level. One commentor who lives in the cleanup area and has a child stated that if the scientific community is not completely clear on what level of cleanup to pick, U.S. EPA should pick the most conservative or safest (lowest) level.

U.S. EPA RESPONSE TO G 1: U.S. EPA agrees with these comments and appreciates the independent analysis submitted that recommended a residential soil lead cleanup level of 500 ppm.

First, based upon the report "Preliminary Assessment of Data from the Madison County Lead Study and Implications for Remediation of Lead Contaminated Soil" by Dr. Marcus, U.S. EPA believes that dust is the primary pathway of lead to the children in the vicinity of the Site and soil lead is the primary contributor to dust lead. Given that the goal is to keep 95 % of the children within the target of blood lead less than 10 ug/dl, U.S. EPA ran the Integrated Exposure Uptake Biokinetic (IEUBK) Model, which is generally accepted by the scientific community, with both default parameters and site-specific data obtained from a 1991 blood study conducted by the Illinois Department of Public Health (IDPH). This exercise yielded a range of protective residential soil lead cleanup levels from 340 ppm to 480 ppm. Using best scientific judgement alone, U.S. EPA would find that the protective residential soil cleanup level for the NL Site to be between 340 ppm and 480 ppm based upon the values derived from the IEUBK model. However, as is more specifically described below, U.S. EPA has decided that a soil cleanup level for the Site of 500 ppm is appropriate. Several factors were involved in this "risk management" decision. First, the 500 ppm is a rounded value at the high end of the protective soil lead values predicted from the model, and hence, EPA believes 500 ppm to be protective. Second, the blood study, even with its inherent limitations, seemed to indicate that the 500 ppm soil lead was causing significant problems in the community. Third, based upon rough cost estimates, lowering the residential soil cleanup level from 500 to 400 ppm will cost approximately 45 to 55% more, and, hence, may be less cost effective. Last, at some concentration below 500 ppm lead, other historic, non-site-related lead sources may contribute significantly to the lead concentrations found in residential soils (background for the area appears to be between 100-200 ppm lead), and, therefore, it may not be appropriate for U.S. EPA to remediate these areas under Superfund.

COMMENT G 2. One commentor stated that 500 ppm lead residential cleanup is an unacceptably high residential soil cleanup level because it allows 5 out of every 100 children to be lead poisoned.

U.S. EPA RESPONSE TO G 2: Consistent with U.S. EPA goals, the cleanup level for lead should be made such that no more than 5% of the affected population will be at risk of having a blood lead level greater than 10 ug/dl.

U.S. EPA feels that 500 ppm, in conjunction with home interior cleaning and efforts to reduce lead-based paint exposure, is a protective and reasonable residential soil cleanup level. It must be noted that the 5% of children that may exceed 10 ug/dl blood lead are not "lead poisoned" but rather are in exceedance of a level of concern for lead in blood. Also, U.S. EPA also believes that allowing up to 500 ppm lead in soil for residential areas, in conjunction with home interior cleaning and efforts to facilitate lead-based paint abatement, is a protective and reasonable residential soil cleanup level.

In essence, a child with 11 ug/dl blood lead is not lead poisoned but is at a blood level of concern where follow-up action should be pursued.

COMMENT G 3. Several commentors felt that the Taracorp pile should be excavated first, followed by paint removal in homes, and then the contaminated residential yards.

U.S. EPA RESPONSE G 3: U.S. EPA would like to clean up all areas at the site simultaneously. However, because of the limited ability of the Superfund to address all the CERCLA sites in the country, only certain amount of money is available at any one time at any CERCLA Site. The amount of money currently available for use at this Site is not sufficient to clean the entire site at the same time. Therefore, we have decided to clean up those areas that present the greatest risk to public health first, and then to proceed to the remaining areas. Had the PRPs agreed to perform the remedy, as requested by U.S. EPA, or had they complied with U.S. EPA's order to clean the Site, there may have been funds available to respond to all the contaminated areas at the Site at the same time.

The areas presenting the greatest risk to public health at the site are the residential yards with lead contaminated soils. These risks include direct contact with and ingestion of lead in the soil due to children playing on the soils. Furthermore, U.S. EPA has been responding to the most highly contaminated residential yards first, and will then address yards with lower contamination, but still above the 500 ppm cleanup level.

By contrast, the Taracorp pile does not currently present as great a risk to public health as the residential yards. Although the Taracorp pile contains much higher lead concentrations than the residential yards, unlike the yards, direct contact with the pile is prevented by use of a fence. In addition, dust from the pile, which can present a risk to public health, is suppressed. Biannually (i.e., once every two years), the pile is sprayed with a surfactant to control airborne dust. Air monitors placed near the pile to test the effectiveness of this spraying show that lead dust levels are well within Federal and State standards considered safe. Finally, although the pile is contributing to groundwater contamination, none of the groundwater within the zone of contamination is used for drinking purposes.

U.S. EPA has taken and will continue to take a global or multi-media approach to addressing the lead contamination at the NL Site.

EPA acknowledges that lead paint is another potential pathway of lead to human health and the environment. Deteriorating lead paint can chip off and then become ground into fine dust. To address this concern, U.S. EPA will continue to work with IDPH and other agencies to address interior and exterior lead-based paint at residences where soil remediation is required. In all instances, every effort will be made to address deteriorating exterior lead-based paint prior to soil remediation in order to prevent recontamination of the soil and thus protect the remedy. These concerns were expressed in comments received during the public comment period, and this procedure was followed by U.S. EPA during previous remediations of residential soils at the NL Site.

In order to clean up interior house dust, a HEPA vacuum and proper training in its operation will be provided to residents whose yards are remediated. HEPA vacuums are used to effectively clean up home interior dust.

COMMENT G 4. One commentor questioned U.S. EPA's contractor, OHM, for disorderly work practices. Several commentors stated that OHM was doing a great job at the Site and were courteous, hospitable, professional, and efficient.

U.S. EPA RESPONSE G 4: U.S. EPA is not aware of any disorderly work by OHM. Although, from time to time U.S. EPA, the Army Corps of Engineers (ACOE) and OHM have fine-tuned the cleanup process after concerns were identified, OHM and the ACOE are doing an orderly and safe job in cleaning the Site. U.S. EPA thanks those commentors who complimented on OHM's work at the Site.

COMMENT G 5. One commentor asked whether contaminated residential property at the Site could be sold without first being cleaned by U.S. EPA. And, if not cleaned, the commentor questioned whether a sign indicating that there is contamination would be placed in the yard.

U.S. EPA RESPONSE G 5: U.S. EPA has heard that some residents have experienced difficulty in selling their property due to the contamination. U.S. EPA does not know who those people are, or what those problems were. U.S. EPA does note that Illinois law requires the seller to disclose any known contamination on the property to be sold. Again, U.S. EPA is not aware how many, if any, homeowners have been affected by that law.

U.S. EPA is not aware of any requirement that homeowners place a sign on the property indicating that the property is contaminated.

Assuming the contamination has presented problems for the sale and financing of residential property at the Site, U.S. EPA's cleanup will remove those problems. It is the PRPs, not U.S. EPA who is responsible for the contamination at the Site. U.S. EPA's cleanup of that contamination will not only allow for the residents of Granite City to be safe from the dangers of lead in soil, it may also increase the value of the residential property at the Site because the contamination will be removed and the yards re-landscaped without any cost to the landowner.

COMMENT G 6. Several commentors felt that the residential soil cleanup is not needed because those commentors have had no problem with lead poisoning in their lifetime.

U.S. EPA RESPONSE G 6:

First, U.S. EPA does not use actual blood lead results as a primary criteria to trigger remediation. U.S. EPA strives to protect those at risk prior to actual exposure and before problems develop. Hence, the lead cleanup is not based on blood lead - but on expected blood lead results. U.S. EPA uses the Integrated Exposure Uptake Biokinetic (IEUBK) Model to predict blood lead for different lead concentrations. U.S. EPA strives to protect the human health and the environment before the populace experiences problems. With regard to lead, EPA targets children in this case since they are the class of people most at risk.

U.S. EPA's goal is to keep 95 % of the children within the target of blood lead less than 10 ug/dl. Even given EPA's goal, and the inherent limitation of the IDPH blood study, the study did show that blood- lead was a problem at this site.

Also, U.S. EPA would like to point out that the commentors have provided no history or medical analysis to show that, in fact, no lead problems have been experienced. Children or pregnant women are the class of people most at risk from lead. The effects of lead may be subtle to severe and that a person may have been affected in childhood without readily apparent symptoms. Furthermore, lead does not affect everyone equally. Exposure is largely due to behavioral tendencies such as the frequency of a child's hand to mouth activity, the level of supervision the child receives, home condition, yard condition, amount of time spent in the home and yard, and nutrition. See more specific response in the Health Comments Section.

COMMENT G 7. Several commentors believe that the Taracorp pile should be removed from the City.

U.S. EPA RESPONSE G 7: U.S. EPA again reevaluated the cleanup options for the Taracorp pile in a separate public notice and comment period that closed on April 19, 1995. For the reasons stated in the Responsiveness Summary for the Taracorp pile, U.S. EPA has decided to retain the previously selected remedy to cap the waste pile. Please refer to the Responsiveness Summary for the Taracorp pile, which comprises Attachment 3 to this DD/ESD.

COMMENT G 8. Several commentors did not understand why the blood study was not considered in selecting the residential soil cleanup level.

U.S. EPA RESPONSE G 8: U.S. EPA has considered the IDPH blood study in selecting the 500 ppm cleanup level for this Site. In addition to that study, U.S. EPA also considered information derived from a computer model which is known as the Integrated Exposure Uptake Biokinetic Uptake Model, designed to predict risks from lead using environmental data collected at the Site. Using the nine criteria in CERCLA and the NCP, U.S. EPA evaluated the cleanup options based on all the information and studies, and selected a 500 ppm cleanup level.

Also, refer to the more detailed explanations in the Health Section.

Furthermore, U.S. EPA believes that there are inherent limitations in blood studies and that blood studies alone should not be the determinative factor of whether or not remediation is required. First, a blood study represents a snap-shot in time of both blood lead levels and behavioral characteristics, such as individuals who modified their home condition immediately prior to the sampling. In addition, the study has various inherent biases. For example, only a percentage of the children in the site area volunteered to participate in the study and subsequently were tested. This group of children may not be representative of the population as a whole. Last, the presence of U.S. EPA and other agencies in the community and lead hazard educational activities undertaken by these agencies may have significantly affected the study because individuals were more aware of lead hazards and thus may have modified their behavior to reduce their child's exposure to lead sources. This may tend to reduce the blood lead level of children in the community as a whole. Unfortunately, these results will not represent the future results if the agencies are no longer active in the community or if people have not permanently modified their behavior.

See more specific response in the Health Comments Section regarding the limitations of the Illinois Department of Public Health (IDPH) blood study.

COMMENT G 10. One commentor felt that it was wasteful of government resources to replace contaminated driveways with concrete driveways. Another commentor commented that U.S. EPA's cleanup of the alleys with concrete was a welcome improvement to the alleys.

U.S. EPA RESPONSE G 10:

Presently, in remediating the contaminated areas, U.S. EPA will replace excavated areas with equivalent materials.

However, in the initial battery chip cleanup activities, U.S. EPA chose to use concrete to replace the excavated areas because U.S. EPA believed only 18 properties had contaminated driveways or alleys and sampling results indicated that the contamination extended several feet below the surface.

Hence, U.S. EPA used concrete to provide extra protection from exposure because it is an effective barrier. However, after discovering that the contamination was not as deep as sampling indicated and that numerous additional locations were contaminated with battery chips, EPA decided to change its plan for restoring the excavated alleys and driveways. Hence, EPA is now restoring excavated areas with equivalent materials. U.S. EPA is trying to work with the property owners to assure that the properties are restored to their satisfaction.

COMMENT G 11. One commentor inquired as to why U.S. EPA would remove soil contamination that was underneath a layer of clean residential soil.

U.S. EPA RESPONSE G 11. In deciding to excavate soils at the Site, U.S. EPA recognized that lead contamination in deeper soils do not present a significant risk threat because, in most cases, those soils do not come into contact with children and do not contribute to the household dust problem. In addition, the sampling results show that nearly all the lead contamination over 500 ppm in the residential yards is within the first 12 inches of soil. Accordingly, U.S. EPA will not exceed approximately 12 inches in excavating residential soil.

U.S. EPA sampling also recognizes that some residential yards have a few inches of top soil that is not contaminated with more than 500 ppm of lead. This may be due to landscaping that was done sometime in the recent past. However, just below this horizon, lead contamination exists. Because every day gardening and child playing activities may expose these slightly deeper layers, excavation is necessary to maintain at least 12 inches of clean soil.

COMMENT G 12. One commentor inquired about any blood testing that had been done on individuals that had lived in the area of the site twenty or thirty years ago.

U.S. EPA Response to G 12. U.S. EPA is not aware that any such testing has been performed. Also, according to ATSDR and IDPH, no such testing was done. U.S. EPA refers the commentor to ATSDR and IDPH for further information.

COMMENT G 13. One commentor suggested that a plant be built on the industrial property site to treat and dispose of all the hazardous wastes from the cleanup including the pile and that somehow a containment structure be built around the site to contain particulate matter.

U.S. EPA RESPONSE TO G 13:

Due to the limited space available, the land ownership structure at the site (4 commercial/industrial properties), and the likely adverse public opinion of such a project, an on-site hazardous waste disposal is not feasible at this site; however, EPA agrees that a containment structure may be necessary to control particulate matter from on-site remediation activities, such as capping the pile. Furthermore, U.S. EPA will assure that effective dust control procedures be undertaken to control any movement of hazardous wastes on or off the site.

COMMENT G 14. One commentor stated that some residents felt forced to allow U.S. EPA to enter their property for sampling ad cleanup.

U.S. EPA RESPONSE TO G 14: U.S. EPA has not applied any coercion or pressure of any kind for the purpose of gaining access to residential yards. U.S. EPA does not know why this commentor felt forced, but U.S. EPA apologizes if there have been some misunderstandings. U.S. EPA's interest is to accurately inform the residents of the dangers from lead contamination, and their right to have their properties cleaned up.

COMMENT G 15. One commentor is disappointed that U.S. EPA did not reopen the public comment period for all aspects of the Site cleanup, and asked why it has taken U.S. EPA so long to begin experiments to determine alternatives to capping.

U.S. EPA RESPONSE TO G 15: Since the time this comment was submitted, in February 1995, U.S. EPA has reopened the public comment period on the Taracorp pile. U.S. EPA also refers the commentor to the Responsiveness Summary for the Taracorp pile.

U.S. EPA has evaluated several alternatives to capping, even as far back as the original Feasibility Study and associated Addendum in 1989 and 1990. Also, studies were conducted in the fall of 1994 to determine the eligibility of the Taracorp pile to be processed or treated at facilities in compliance with Federal and State law. These studies show that, among other factors, the cost of removing the pile was too high to justify using less extensive cleanup options, while providing a similar degree of risk reduction.

WRITTEN TECHNICAL COMMENTS

COMMENT T 1.

One commentor expressed concern for recontamination of residences that have been remediated by removal or capping of the Taracorp pile.

U.S. EPA RESPONSE TO COMMENT T 1:

U.S. EPA thanks the commentor for the concern. U.S. EPA assures the commentor that lead dust emissions will be adequately controlled during capping of the Taracorp pile such that significant recontamination (i.e., to greater than 500 ppm lead) will not occur from the capping activities. U.S. EPA has been extremely successful in controlling lead dust to acceptable levels during the remediation of numerous battery chip fill areas with high lead concentrations (up to 100,000 ppm lead). The Taracorp pile will present additional challenges because of its height and higher lead concentrations(up to 300,000 ppm lead); however, U.S. EPA will upgrade dust control measures, as necessary, to deal with these challenges. The technology exists to control lead dust from the pile. The only drawback is that additional dust control measures will cost more.

COMMENT T 2.

One commentor submitted a report containing a cost estimate for residential soil remediation assuming excavation of soil to a level of 500 ppm. The response below addresses this report and its main conclusions that EPA has been very inconsistent with its use of its own cost estimates, EPA was allocating approximately two to three times the amount of money per residence than was actually needed, and EPA's property characterization was flawed, creating the potential that entire properties would be remediated where only hot spots exist.

U.S. EPA RESPONSE TO COMMENT T 2:

U.S. EPA thanks the commentor for the independent cost estimate and concerns over EPA's sampling protocol. Regarding estimates of costs to perform remedial work, the U.S. EPA's estimate of $42 million dollars to remediate 1300 residences to 500 ppm is reasonable and is supported by the public record.

However, the commentor has provided estimates with a $53 million dollar range (i.e., $82 million to $29 million) for the residential soil cleanup. These estimates were based on a short period of observation and included the exaggerated start up costs for a rapid response action. The reason that the start up costs are exaggerated is, as explained further below, that U.S. EPA was presented with a temporary restraining order filed by the City of Granite City after cleanup had begun on only several residential properties. The remediation work performed by EPA starting in August 1994 is not indicative of expected actual remedial costs since the City of Granite City issued a temporary restraining order against EPA's remedial work, causing numerous start-ups and shutdowns and drastically increasing costs to perform the work. Any cost estimate based on figures from the work that commenced in August 1994 is, thus, greatly overinflated.

Also, as is acknowledged by the commentor, there are physical differences to the different properties along with somewhat differing contamination which directly contribute to the different actual costs for remediating a residence and the seemingly inconsistent estimates.

Regarding U.S. EPA's sampling protocol, EPA believes that the current protocol is designed to properly characterize representative contamination on the properties. The time and monies spent in labor and sampling to find these postulated hot spots on each residence would not be fruitful since 1) in an airborne deposition pattern such as existed at the NL smelter, significant hot spots would not be expected to occur within the yards, and 2) since the only other likely source of lead hot spots, such as soil lead deposition from exterior lead-based paint, was specifically avoided in EPA's sampling protocols.

COMMENT T 3.

One commentor identified, in a report, various problems that the commentor observed with the residential soil cleanup activities undertaken by EPA starting in August 1994. These problems, according to the commentor, included inadequate air monitoring, inadequate site security, cross-contamination of clean areas outside the excavation zone, recontamination of residences being cleaned up, and damage to the City's infrastructure.

U.S. EPA RESPONSE TO COMMENT T 3:

U.S. EPA thanks the commentor for the concern. However, EPA believes that the commentor has drawn his or her conclusions were based on only two days of observations and that the observations were not representative of normal remedial activities. One of the U.S. EPA goals for the remedial activities is to assure that the public health and safety is considered at all times. Following are specific responses which answer the specific concerns.

The contractor has a Site Safety and Health Plan which covers all the concerns about safety for this project including traffic, pedestrians/school children and emergency numbers. Safety is the number one priority and there has only been one accident, which was not the contractor's fault.

Site security is first addressed through verbal communication with all residents.

Fences remain in place at the end of each day if any further work remains for the next day. Any stockpiles of special waste which remain on the property at the end of the day are covered with plastic and weighted down that no contact with the waste will occur.

All excavation activities are performed in a manner that would minimize any fugitive emissions and prevent cross contamination and recontamination. A "no visible dust emissions" protocol has been instituted. The dust emissions are controlled by constant wetting of excavation activities. Also, other activities are performed to assure no recontamination is occurring; for example, excavation equipment is located on the contaminated areas while performing the actual excavation.

All air monitoring is conducted in accordance with U.S. EPA and OSHA standards. Results of air monitoring performed to date for remedial activities have indicated that lead air emissions have been well within applicable standards on every day that excavation activities were performed. See also response to comment T6 below.

When unavoidable damage to city property has occurred, the property has been repaired immediately as can be attested to by the city's Inspector, Mr. Glenn Hollis. All coordination of activities were not only directed through his office but the city's Mayor provided anyone who called with the EPA/U.S. Army Corps of Engineers On-Site Representative's Office telephone number.

COMMENT T 4:

One commentor provided a comparison of 500 ppm and 1000 ppm residential cleanup level in light of eight of EPA's nine criteria (State acceptance was not addressed) and argued for the 1000 ppm residential soil cleanup level for lead.

U.S. EPA RESPONSE TO COMMENT T 4:

U.S. EPA thanks the commentor for the independent analysis, however, U.S. EPA believes that the selected remedy for the NL site, including the residential soil cleanup level, is justified in the March 1990 Record of Decision (ROD) and the 1995 Decision Document/ Explanation of Significant Differences (DD/ESD). The selected remedy was based on U.S. EPA's analysis of the nine criteria as is required by the National Contingency Plan and CERCLA. The discussion in the 1990 ROD and the 1995 DD/ESD will not be repeated here; however, several points shall be highlighted.

First, EPA does not agree that a 1000 ppm cleanup level is equally protective of human health and the environment as 500 ppm. A lower cleanup level is inherently more protective. EPA not only believes that 500 ppm is more protective, but that 500 ppm is the maximum concentration of lead in residential soil that will still meet the criterion of Overall Protectiveness of Human Health and the Environment at this site. Further details on this matter and the fact that EPA believes that using the 500 ppm cleanup level will result in a statistically significant reduction in blood lead levels are provided in response to the health comments that follow in Section 4 of this Responsiveness Summary.

Additionally, in decision process, U.S. EPA has used the Integrated Exposure Uptake Biokinetic (IEUBK) Model to evaluate potential risks to children from lead exposure in residential settings and to set the selected cleanup level. The model which is generally accepted by the scientific community as is described further elsewhere in this responsiveness summary, was run as part of the risk assessment to determine a protective residential soil cleanup level for lead and yielded levels of 340 to 480 parts per million (ppm).

Lastly, U.S. EPA disagrees with the statement that U.S. EPA does not have community acceptance of its remedy. While it is true that the City government of Granite City has opposed the remedy from the beginning, hundreds of visits to Granite City and Madison residents have provided EPA with a very strong basis to judge community acceptance of the remedy. EPA firmly believes that the majority of residents favor the residential soil cleanup. In fact, a glance at the transcript of the public meeting for this comment period should point out that the community supports EPA's selected remedy. In EPA's opinion, which is based on hundreds of personal contacts with residents in the cleanup zone, the City of Granite City is not representing the view of the majority of its citizens in this area, and the City has received numerous criticisms of its actions to halt EPA's cleanup from many of its citizens. Petitions were circulated and signed by numerous residents regarding the City's attempts to stop the residential soil cleanups. By contrast, when requested, the City of Madison has granted EPA access for sampling and remediation of contaminated property it owns, and the City of Venice and the community of Eagle Park Acres have been extremely cooperative and appreciative in allowing EPA to conduct numerous battery chip fill removals in these communities. The commentor limited his/her discussion to the opinions of the City of Granite City; community acceptance must be gaged by the opinions of entire affected community, and this is why EPA disagrees with the commentor's statement that "U.S. EPA quite obviously does not have community acceptance of its proposed remedy".

COMMENT T 5:

The City of Granite City submitted extensive comments that raised the following issues: (a) that EPA has failed to substantiate how it will be able to proceed with either capping or removal of the Taracorp pile without contaminating surrounding properties and/or recontaminating properties that were already remediated, (b) that EPA's failure to make a decision concerning the pile remediation will be damaging to the City's social and economic well-being, (c) that EPA's remedy may reduce property values in Granite City during the time EPA expects to perform/complete the remedy, which may be 10 years based on the work done to date, (d) EPA's remedy will affect business and commercial interests in the downtown area, (e) EPA will allow the major source of lead, lead-based paint, to remain in the site area, and, thus, removing soils will have no consequential impact on the blood lead levels of the children, and (f) that EPA's cleanup has and will continue to cause traffic disruption and damage to the City's infrastructure. Reports were submitted in support of some of these comments.

U.S. EPA RESPONSE TO COMMENT T 5:

The U.S. EPA thanks the commentor for raising the concerns. U.S. EPA believes that the selected remedies are the most protective, reasonable, cost-effective remedies of all the alternatives considered and, once implemented, will be a benefit the affected communities. The following responses will address the concerns.

(a) EPA believes that capping the pile will not contaminate surrounding properties. This issue is addressed in the response to comment T1 above in the responsiveness summary for the Taracorp pile and the ground water (Attachment 3).

(b) EPA has made a decision regarding the pile. See response to Comment #G 12.

(c) EPA's remedy will not reduce property values in Granite City during the remediation. After a resident's yard is cleaned up, the value is expected to increase since the known contamination has been removed. The remediated yards should also be easier to sell since the contamination that was removed will no longer be a hindrance to sale under the Illinois Real Property Transfer Act. It is very disappointing that the City of Granite City would make any estimate of the length of time it will take to clean up the residential yards that is based on EPA's work performed after August 1994 since this work was delayed significantly due to the City's own actions to bring a Temporary Restraining Order to halt

EPA's cleanup of the most highly contaminated residential yards. The City is trying to strengthen a point over which it had a direct influence; EPA's work would have been performed more quickly, efficiently, and cost-effectively in the absence of the City's efforts to stop the cleanup.

(d) The disruption to the businesses caused by implementation of the remedy will be minimal. The response to this comment is similar to response (f) below in that it is not clear how EPA's remedy could disrupt the businesses in the downtown area via traffic congestion even nearly as much as the hundreds of trucks that pass through Granite City each day due to the steel mill and other industries in the same vicinity as the site. EPA's action will produce an insignificant increase in the volume of traffic through Granite City, and EPA will not be using railroads for any of its activities, which is a source of delays and congestion that residents of the City must deal with every day.

(e) EPA believes that the selected remedy will address the major sources of lead at the site and that soil removal will have a significant beneficial effect on the health risks to children from lead. Some of the residences may also have deteriorating lead paint which can also be a health threat. EPA will try to work with other agencies to address the lead source. A detailed response to this comment is provided in the response to the health comments that follows.

EARTH SCIENCES REPORT

The following responses address statements made in the Earth Sciences report attached to the City of Granite City's comments.

Earth Sciences Consultants, Inc. (Earth Sciences) was retained in order to evaluate, from an engineering perspective, the remedial action program planned and implemented in part by the U. S. EPA at the NL Industries/Taracorp site in Granite City, Illinois.

In August 1994, the Chicago District of the United States Army Corps of Engineers (USACE) entered into a contract with OHM Remediation Services to remediate and restore 70 residential properties contaminated by stack emission fallout in Granite City. EPA has not initiated an emergency removal action to excavate and replace lead-contaminated soils at a number of residential properties in and around Granite City as stated in the report. Earth Sciences was subsequently retained to review and evaluate the residential soils replacement program. The reader is referred to the Earth Sciences Report for a full reading of each of the comments made in the report.

COMMENT T6: Earth Sciences evaluation, Executive Summary and Review of Air Monitoring Program on pages 3, 4 and 5 concerning air monitoring, site security, emissions, priority of remediation, and costs of remediation.

U.S. EPA RESPONSES TO COMMENT T 6:

U.S. EPA thanks the commentor for the concerns. Below are specific responses to the issues raised.

a. The Site Safety and Health Plan covers all the concerns about safety for this project including traffic, pedestrians/school children and emergency numbers. Health and safety is the number one priority. All air monitoring is conducted in accordance with U.S. EPA and OSHA standards. Results of air monitoring performed to date for remedial activities have indicated that lead air emissions have been well within applicable standards on every day that excavation activities were performed. OSHA standard for lead is found in 29 CFR 1910.1025, perimeter limits for personnel exposure; the permissible exposure level (PEL) = 50 ug/m3 which is equivalent to 0.05 mg/m3 for an 8 hour time-weighted average (TWA). The contractor has established an action level of 50 ug/m3 as a perimeter limit which is beyond the immediate work zone. Inside the work zone the contractor has established an action level for worker safety at 1.5 ug/m3 or 0.0015 mg/m3, this level meets or exceeds the established requirements. In addition, no visible dust emissions are allowed during excavation of contaminated materials. These measures comply with Section 9.0 of the Site Safety and Health Plan for the project. All documentation regarding the rationale for selection of upwind vs. downwind air monitoring stations can be found in U.S. EPA's Contractors' Daily Report.

b. Site security measures are implemented at each residence in a personal manner. U.S. EPA's contractor takes all the appropriate actions and steps necessary to ensure a safe remedial action as cost effectively as possible.

c. No visible dust emissions are allowed, and at all times during the excavation of contaminated materials. One person on site is responsible for assuring this requirement is met.

d. All sites remediated were prioritized by lead concentration levels, children and contiguousness for cost effectiveness. Any documentation needed will be provided upon request. All inventory is tracked daily.

e. Most of the additional and unanticipated costs incurred are due to the court proceeding for the Temporary Restraining Order issued by the City of Granite City has been previously discussed. For example, when the court proceedings caused the work to shut down and additional costs are associated with demobilization and remobilization of contractor personnel and equipment.

COMMENT T7; page 6, paragraph 5.0 of the Earth Sciences Report:

The comment concerns security, cross contamination and the potential for recontamination. A videotape was presented.

U.S. EPA RESPONSES TO COMMENTS T 7:

U.S. EPA thanks the commentor for the concerns. In general, the videotape provides a depiction of proper site safety procedures and good work practices. The Site Safety and Health Plan covers all the concerns about safety for this project including traffic, pedestrians/school children and emergency numbers. Safety is the number one priority. However, below, U.S. EPA has addressed what appears to be concerns by the commentor.

a. Site Concern #1: Site Security Concern (videotaped by a representative of Coburn & Croft on August 10 and 17, 1994). At 1627 Edison and 1635/1641 Delmar on August 10, 1994, the video shows a child watching the excavation activities outside the work area. It is not clear what is intended by this depiction. However, the person videotaping the activities was warned on several occasions to stand back out of the way by the Safety Technician.

Site security is first addressed through verbal communication with all residents. The general practice is to caution residents that it is prudent to avoid any exposure. In practice, EPA has dictated that in order to alleviate concerns of the nearby residents of exposure to lead dust and to diminish cross contamination, "<u>NO VISIBLE DUST EMISSIONS ARE ALLOWED</u>";

Site Concern #2: Site Security Concern. The scene at 1621 Delmar videotaped on August 17, 1994 shows a site that had been remediated, all contaminated soils had been disposed of and the site was not yet in the process of being restored;

Site Concern #3: Site Security Concern. The scene shown at 1728 Cleveland on August 17, 1994 of someone eating on their front porch with loadout of materials taking place in their back yard. At this point in the process, the excavation of the contaminated materials had already taken place. The resident was apparently enjoying a nice day where it was less noisy and since there was no dust.

> Site Concern #3: The scenes showing OHM personnel going in and out of the site. The area that the contractors are moving in and out of is the area that has already been remediated and restoration activities are occurring. It is not the exclusion zone which signifies the contaminated area. The work is conducted in accordance with EPA approved protocols and an established Site Safety and Health Plan. This plan has been amended based upon problems which have been encountered early in the project.

COMMENT T 8; page 6, Paragraph 5.2 of the Earth Sciences Report:

The comment concerns cross-contamination and U.S. EPA's contractors work ethic. A videotape was presented. The videotape which was made by a representative of Coburn & Croft on August 10 and 17, 1994.

U.S. EPA RESPONSE TO T 8:

U.S. EPA thanks the commentor for the concerns regarding irregularities in remedial work activities.

U.S. EPA along with USACE and its contractors' are to consider public health and safety are considered at all times during the operation. The work has been conducted with this in mind. After viewing the tape, In general, the videotape provides a depiction of proper site safety procedures and good work practices. However, below U.S. EPA has addressed what appears to be concerns by the commentor.

> Site Concern #1: The scene shown at 1627 Edison on August 10, 1994, and the report of personnel standing Plywood sheets on their edge to clean out soil. The plywood was laid down to protect the streets and sidewalks from damage as clean equipment is driven onto the site to remediate it. It is not contaminated dirt depicted in the scene since the site was not loaded out until the next week.

> Site Concern #2: The site at 1627 Cleveland was never remediated by U.S. EPA. Hence, the scene of piles at this site were not caused by U.S. EPA.

> Site Concern #3: The site at 1630 Cleveland on August 17, 1994, had been remediated. The dirt depicted was clean; OHM placed clean fill dirt over the sidewalk to protect it from damage while being loaded out the next day.

Site Concern #4: The apparent concerns presented for the site videotaped at 1726/1728 Cleveland on August 17, 1994, may be alleviated if the commentor were to understand the standard operating procedures. This property was remediated exactly like all others. Equipment has rubber tracks which are cleaned before it reaches the remediated area. Hence, any soil that the tracks may pick up then is clean. The same is true of the water running off the remediated area. As was previously mentioned, in accordance with established protocols, it is the USACE on-site representative's responsibility to ensure that no visible dust emissions are allowed.

Site Concern #5: The apparent concerns of irregularities at 1624 Delmar on August 17, 1994 may be alleviated if the commentor understood the standard operational procedures. It is standard practice that after a truck is loaded, it is covered, then its tires are decontaminated. At the time of loadout, the only exclusion zone with controlled entry and exit is under the pile of contaminated soil. OHM's personnel wear protective booties, as do the truck drivers to keep their feet decontaminated and dry due to constant spraying and wet conditions. Hence, the operators do not have to under go "decontamination" procedures.

Site Concern #6: The commentor alleges that the residents at 1419 Grand Avenue have noting heavy accumulations of dust and dirt during OHM's activities. While it's quite possible that clean topsoil materials being placed may generate dust during the restoration process when . During the restoration process backfill and topsoil is tracked on sidewalks and streets. However, in accordance with the standard operating procedures, it is OHM's responsibility to clean up the work areas. However, "no visible dust" is allowed from remediation of contaminated soil.

COMMENT T 9; Paragraph 5.3 of the Earth Sciences Report:

The comment is regarding re-contamination concerns. Photographs were presented.

U.S. EPA RESPONSE TO COMMENT T 9:

U.S. EPA thanks the commentor for the concerns regarding cross-contamination during remedial work activities. A record of the photographs was made by Earth Sciences and REACT personnel on August 31, 1994. U.S. EPA is not always clear what issues are depicted by the photographs are; however EPA will try to be responsive to what may be a concern.

Photograph #1 shows concrete that had been decontaminated and the sites had been remediated. No contamination remains.

Photograph numbers 6, 7, 8, 10, 11, 13, 15, 17, and 21; same response.

COMMENT T 10; page 7, paragraph 2 of the Earth Sciences Report:

The comment is regarding concerns of traffic-related problems, economic impact and public acceptance of the remedial activities.

U.S. EPA RESPONSE TO COMMENT T 10:

U.S. EPA thanks the commentor for the concerns of traffic-related problems, economic impact and public acceptance during the remedial activities. There is already many trucks due to the fact that the City's truck route encircles the areas to be remediated and the area is industrialized.

The lead remediated properties and new lawns have actually raised property values. In just several blocks in the contaminated area, there were approximately 140 residence owners who wanted their properties remediated with at least three community action groups actively seeking signatures for petitions for the work to continue. All allegations on this page was answered in the previous response.

COMMENT T 11; page 9 of the Earth Sciences Report:

The commentor has concerns regarding traffic incidents and specifically that a number of streets and alleys have been blocked or partially blocked for weeks and months at a time during the U.S. EPA remediation.

U.S. EPA RESPONSE TO COMMENT TO T 11:

U.S. EPA thanks the commentor for the concerns; however, any vehicles which have blocked alleys for weeks or months were not those involved with the U.S. EPA remediation. The longest time period that a vehicle involved with the remediation may have blocked a street or alley is 10 hours. U.S. EPA and its contractors have coordinated these activities with the Mayor and City Inspector of Granite City. Additionally, no accidents have occurred and all city property is repaired. The City Inspector is pleased with the remediation contractor's cooperation and timeliness. All residence owners, with very few exceptions, are pleased with the restoration of their property as can be seen in the public meeting transcript.

COMMENT T 12:

A report was attached to the City's comments presenting concerns of traffic-related incidents. This report alleged that a large number of trucks were parked along streets and a significant increase in truck traffic occurred.

U.S. EPA RESPONSE TO COMMENT T 12:

U.S. EPA thanks the commentor for the concerns; however the standard operating procedures are established to minimize disruption to the local traffic and the community. Trucks may be parked along the street at the start of the work day whereas the most trucks ever parked at any one time were seven, as they began loadout of materials. After the initial loadout of the seven trucks was completed, no more than two were parked thereafter. In addition, in general, trucks are not allowed to sit idle; maybe two idol trucks were on the street at any given time.

Regarding the alleged increase in truck traffic, U.S. EPA has the opinion that no significant increase in truck traffic has occurred. A significant volume of truck traffic is already present in Granite City due to the many industries in the area of the site. In fact, Mr. Fitzhenry, the attorney for the city of Granite City, has recently stated that truck traffic from the residential soil remediation activities is not an issue.

WRITTEN HEALTH COMMENTS

THE GRANITE CITY LEAD EXPOSURE DATA SET: IEUBK MODELING AND EVALUATION OF SOIL LEAD AS A RISK FACTOR,
by Gary L. Ginsberg and Gale L. Hoffnagle, TRC Environmental Corporation
Submitted on January 6, 1995

COMMENT H 1 (TRC-OBJ1); Page 1, lines 6-7 from bottom: "The blood lead distribution shown for Granite City children is typical of that expected for urban areas."

U.S. EPA RESPONSE TO COMMENT H 1:

Neither the Madison County Lead Study area nor the vicinity of the NL/Taracorp site (hereafter denoted in brief as the NL site) are demographically similar to major urban areas or to smaller urban areas (less than one million people). There is a significant association between blood lead and lead in household dust in the Madison County Lead Study, where most of the lead in household dust is derived from lead in soil in the areas closest to the NL site even after adjustment for demographic or behavioral factors and for the existence of deteriorating lead-based paint that was found in some of these houses. The incidence of elevated blood lead concentrations within about a quarter mile of the NL site is about 25 percent of children younger than 6 years of age (hereafter called 'pre-school children'), compared with about 10 percent in the distant parts of Madison County, and 16 percent in smaller urban areas in the NHANES III study. The difference is statistically significant. Deteriorating lead-based paint is one source of lead that is often found in older urban areas, and undoubtedly contributes some cases of elevated childhood lead exposure in Madison County Lead Study, but there is no reason to believe that the incidence of elevated blood attributable to lead paint should differ from other small urban areas. However, the proposed remediation area around the NL site contains lead sources, predominantly in soil, that pose an extra risk to young children who live there. Some children farther away from the NL site, in communities such as Eagle Park Acres or Venice Township, are exposed to other significant identifiable sources of lead, including yards or play areas contaminated by battery casing chips and by materials from the waste pile used for street repair or yard fill, which are hardly the most common lead sources in other urban areas.

Additionally, it is not appropriate to deemphasize the importance of cleaning up significant lead contamination in one community just because other communities may also have significant lead contamination. This statement is made in different forms throughout these comments, and U.S. EPA disagrees completely with this attitude and the statements that it is acceptable to have

16% of the children tested in the Madison County study area between ages 6 months and 6 years with a blood lead in excess of 10 ug/dl because it is typical of other smaller urban areas. Such an approach obscures potential public health problems and is of little consolation to individuals who may be adversely affected by situations such as that near the NL site.

COMMENT H 2 (TRC-OBJ2); p. 1, 4-6 lines from bottom: "While statistical analyses of the environmental lead/blood lead relationship are confounded by a variety of covariant parameters, soil lead is unlikely to be a major explanation for elevation in blood lead."

U.S. EPA RESPONSE TO H 2:

EPA performed a variety of multivariate statistical analyses using the Madison County Lead Study data. These analyses showed that dust lead is the most significant environmental contributor to childhood blood lead, even after adjusting for modifying factors such as the child's age, family or household demographic characteristics, child-specific behavioral characteristics such as mouthing of non-food objects, and condition of the building or of the paint on the building. However, it is important to recognize that household dust is a pathway for exposure -- the major pathway for most preschool children -- and not a source in itself. Primary sources that contribute lead to household dust include lead in yard soil and lead in interior paint. While both sources are important, our analyses show that yard soil is a much more important contributor to lead in house dust than is lead paint for most houses closer than a mile from the NL site. The primary, but indirect role of soil lead can be resolved by appropriate analyses.

COMMENT H 3 (TRC-OBJ3); p. 1, bottom 2 lines, and p. 2, top 2 lines of the report: "The default model used by EPA to derive a soil lead cleanup level (Marcus, 1994) is not predictive for the cases in which soil lead exceeds 500 ppm. The slope between blood lead and soil lead (ug/dl change per 1000 ppm change in soil lead) is overpredicted by approximately 4-fold by the default model."

RESPONSE TO COMMENT H 3:

We have examined the predictiveness of the IEUBK model in some detail in preparing our initial assessment and later in evaluating this comment. The IEUBK model provides generally accurate predictions for soil lead concentrations less than about 1000 ppm. The predictive range for the IEUBK model applied to data from the Madison County Lead Study includes the usual decision range for soil lead remediation, 400 to 1000 ppm, and lower concentrations. The model tends to overpredict blood lead concentrations somewhat for higher soil lead concentrations, but by much less than a factor of four suggested in this comment. A number of plausible alternative explanations may be proposed for this difference, as discussed in the next Response. Neither the IEUBK Model nor "slope factor" models such as those used by EPA in the Air Quality Criteria for Lead (U.S. EPA, 1986) can estimate individual deviations from mean predicted blood lead caused by intrinsic random variability attributable to inter-individual differences in exposure, absorption, and biokinetics of tissue distribution and elimination.

COMMENT H 4 (TRC-OBJ4); p. 2, lines 5-7 of the report: "The best performance of the model is attained by decreasing the soil/house dust lead uptake (absorption) coefficient under conditions of high environmental concentrations."

U.S. EPA RESPONSE TO COMMENT H 4:

A number of plausible explanations may be proposed for differences between observed and predicted blood lead concentration, including: (1) both soil lead and dust lead concentrations were measured by protocols that differ somewhat from the protocols used in studies for which the IEUBK model was originally validated. These include the inflation of dust lead concentrations by inclusion of large particles such as paint chips. This occasionally made a large difference, since some of the extremely large dust lead concentrations occurred in locations with moderately elevated soil lead concentrations, and showed the largest mismatches between observed and predicted blood lead; (2) the contribution of soil lead to household dust lead may be somewhat smaller than the standard model assumption of 70 percent, especially near the NL site; (3) bioavailability of lead in particles may be different for dust or soil particles from different sources, such as differences among particles from battery chips and waste pile materials used for fill, particles derived from chips or flakes of lead paint, and airborne particles deposited as fugitive emissions from the waste pile or historical emissions from the smelter stack. Differences in bioavailability associated with location seem less plausible than differences in dust and soil sampling or analysis from standard methods used in other studies, or differences in movement of soil into household dust. The differences in transport may be attributed in part to greater awareness of potential lead hazards among residents near the site, but in the absence of a suitable control group, any hypotheses about the role of caretaker awareness in mitigating childhood exposure to dust and soil remain speculative. There were no systematic effects of child age between observed and predicted blood lead concentration. The model underestimated blood lead concentration among children identified as non-white (especially African-American), even after adjusting for environmental lead, with every set of model parameters used in the sensitivity analyses. Several multivariate statistical analyses also found this difference, even after adjusting for differences in sociodemographic characteristics and environmental lead.

The commentors suggested using a post hoc calibration of the absorption parameters of the IEUBK model using alternative percentages in Table 2 of the TRC report. The recommendation in the IEUBK Model Guidance Manual is that post-hoc calibration of the Model using cross-sectional data be avoided without strong biological or physical evidence based on properties of the soil and dust on the site. In fact, a number of plausible alternative explanations for the observed pattern of deviations are described in EPA responses to detailed comments below, especially TRC-9.

COMMENT H 5 (TRC-OBJ5); p. 2, lines 13-15, 17--21 of the report:

"The calibrated model demonstrates that soil lead remediation to even very low concentrations (e.g. 200 ppm) would have only a slight impact upon blood lead as indicated by the limited effects of soil lead on indoor dust lead. ... Rather than focussing upon soil lead mitigation, a combined approach involving parental education, mitigation of strong lead sources (such as lead paint in poor condition, and grossly elevated soil and dust lead concentrations) may be the most effective approach, if it is decided that an intervention program of any kind is needed in this community."

RESPONSE TO COMMENT H 5:

Within existing EPA program constraints, a multimedia approach dealing with the diverse potential sources of lead exposure in a household would be preferred. The analyses developed by EPA suggest that in a substantial number of residences within the remediation area near the NL site, the primary exposure problem resulting in observed cases of blood lead of 10 ug/dl or greater is clearly attributable to 'grossly elevated soil and dust lead', which is sufficiently greater than the probable contribution of lead paint or other environmental sources in these households as to suggest that, by itself, soil lead remediation would be an important action in preventing lead exposure for present pre-school residents, and more importantly, for new occupants of the same residence. Remediation of a yard with high soil lead concentration would also help to prevent recontamination of the residence and would contribute to a community-wide reduction in exposure, particularly in nearby remediated residences. The effectiveness of remediating soil lead has been demonstrated in the first year of the Boston component of the Urban Soil Lead Abatement Demonstration Project (USLADP; Weitzmann et al., 1993) with reductions at least as great in the second year after abatement (Aschengrau et al., 1994), and in ongoing remediation at the CERCLA site in the Silver Valley of Idaho (Von Linden et al., 1995). Remediation may be most effective when soil lead is clearly a major source of exposure and of potential household dust contamination, and where recontamination of the residence can be prevented. Parental education and other behavioral interventions may also be effective, but this requires a constant effort for each new household with young children that moves into the residence, for as long as the lead sources in soil and paint remain and the residence can become recontaminated (i.e. intervention is not a permanent remedy).

COMMENT H 6 (TRC-OBJ6), p. 2, lines 15-17:

"Many children who have elevated blood lead do not live in elevated soil lead areas. The blood lead/soil lead slope factor relating blood lead to soil lead is thus shallow."

U.S. EPA RESPONSE TO COMMENT H 6:

Soil lead concentration may not by itself be an adequate predictor of child blood lead concentration without knowledge of site-specific soil transport and uptake properties.The map in Figure 1 of the IEHR/IDPH report on the Madison County Lead Study shows that the areas with the highest incidence of housing containing children who have elevated blood lead is in the area near the NL site and essentially "downwind" of the site, but that there are some pockets of elevated blood lead in more remote areas such as Venice Township and Eagle Park Acres that are probably attributable to other identifiable sources, such as battery casing chips. Unfortunately, in spite of repeated requests, IEHR/IDPH has failed to provide EPA with data that would allow this observation to be evaluated in detail. The commentor, presumably, also has no basis for separating these areas from equally distant parts of Granite City or Madison where the primary soil lead source was historical emissions from the now-closed smelter, which may differ in potential lead hazard from the battery casing chips and from waste pile material used as soil fill in Venice and Eagle Park Acres. A meaningful "slope factor" cannot be calculated without such separation by potential lead source. For example, if there is very low soil-to-dust transport or bioavailability of lead from one source, then the blood lead vs. soil lead slope factor will be much lower than for otherwise similar soil lead concentrations where soil lead is either more readily transported into house dust, or is more bioavailable than soil lead from another source. This is discussed at length in the IEUBK Model Guidance Manual in order to prevent over-simplification of the sort demonstrated by this comment.

COMMENT H 7 (TRC-OBJ7); p. 2, lines 24-25, 30-33 of the report: "EPA's critique focused upon a spatial relationship between blood lead and soil lead which is confounded by a variety of covariates. ... the association between soil lead and elevated blood lead is weak and not statistically significant. Other environmental (particularly paint lead) and behavioral/socioeconomic factors are likely stronger influences in creating blood lead exceedances."

U.S. EPA RESPONSE TO COMMENT H 7:

This is an interesting speculation by the commentor, which we have tested extensively using several multivariate methods, as described in an accompanying report. In essence, soil lead concentration is a weak **direct** predictor of blood lead, whereas **dust lead** is one of the **strongest direct predictors of blood lead**. However, **soil lead is the strongest direct predictor of dust lead** in empirical statistical models we have tested, and is generally stronger than or about as strong as lead paint as a predictor of dust lead. Most of the socio-demographic variables are covariates of blood lead, and sometimes of dust lead, but on a child-by-child and residence-by-residence basis, show relatively weak confounding with lead in soil, and do little to modify the estimated effects of soil lead on dust lead. The reason why soil lead plays an important but indirect role is easy to understand. Soil lead is a potential source of lead in household dust. The soil-to-dust pathway may be reduced by any of several interventions, for example by using doormats and by removing street shoes at the entrances of the residence. Conversely, the transport of soil into house dust can be increased by the presence of indoor-outdoor pets, or by outdoor activities such as playing or gardening in yard soil when these activities allow more soil to be tracked into the residence.

Dust lead tends to have a relatively variable relationship to soil lead in different residences, sometimes low and sometimes high, and differing even in repeated measurements of the same residence. Dust lead loading depends on whether the particular household had been dusted at the time when the study was done and on the relative ease of dusting the residence, and may be subject to large changes when other residents occupy the same housing. Lead-based paint also has a somewhat variable relationship to household dust lead, depending on the frequency of house cleaning and the attention paid to maintaining or stabilizing surfaces with deteriorating paint. In the areas nearest the NL site, the deteriorating lead paint loadings are not much higher than the loadings further away from the site, whereas the soil lead concentrations are much higher.

EPA has used several multivariate statistical methods to analyze the relationships among environmental lead variables. In most houses near the site, the contribution of soil lead to dust lead is estimated to be much higher than the contribution of lead paint to dust lead. At some distance from the NL site, the soil lead concentrations are much lower and so typically are the dust lead concentrations and loadings, but there is a clear correlation with deteriorating interior lead paint. The lead paint contribution to dust lead is dominated by the soil lead contribution near the NL site. Because soil lead and paint lead are indirect sources of lead in the child's blood, acting through dust lead as intermediate pathway, neither soil lead nor lead paint are significant predictors of blood lead when dust lead is included as a predictor of blood lead. Dust lead appears to be a much more important direct medium of childhood exposure (the more "proximate" exposure medium) than either soil or paint chips. It is not possible to understand the weaker relationship of the primary lead sources (soil and paint) to blood lead without understanding that dust lead is the appropriate marker of potential exposure.

The behavioral and demographic covariates show some relationship to distance, but are not strong confounders. A confounding variable must be related to both the response (e.g. blood lead) and the nominal causal agent (e.g. soil lead). Within each distance "ring", most potential confounders such as age, mouthing behavior, parental income and education are not strongly correlated with soil lead, but are more closely correlated with blood lead. It is thus possible to separate the effects of these potential confounders apart from soil lead and dust lead. The scientific basis for the lack of serious confounding is that many of the sociodemographic and behavioral variables affect the rate of contact with or ingestion of soil, dust, paint chips, and other media, but have little relation to the amount of lead in each environmental component. There wouldn't be any lead in the child's blood without lead in some environmental medium encountered by the child, where the environmental media include food, drinking water, air, medicines and cosmetics, and accidental ingestion of soil, dust, or large paint chips. Even if the child's lead was acquired from the mother's lead exposure and passed on to the child during pregnancy or lactation, all of the lead in the child must ultimately come from some environmental source, and the behavioral and demographic variables can at most modify the amount of lead that the child has taken up from some current or historical exposure to environmental lead. Therefore, while it is useful to include some of the behavioral and sociodemographic variables in a statistical analysis because they help to explain the inter-individual variability in blood lead, they are at most modifiers of the uptake of lead from some environmental lead exposure pathway or source.

EPA analyses use distance from the NL site as an indicator of potential source of lead in soil near the site. In fact, one the strongest relationships among all of the variables evaluated in the data set provided to us is that lead in soil is nearly inversely proportional to distance from the site. Apart from this, the commentors' speculations about the confounding effects of distance-related variables have little factual basis, once the two-phase nature of the relationship of blood lead to soil lead, through dust lead, is recognized.

COMMENT H 8 (TRC-OBJ8); p. 2, lines 25-28 of the report: "In the first instance, EPA appears to misinterpret the use of the spatial correlation in the study. It was not intended as a method for comparing areas. Rather, it was simply intended to assure that a representative sample was obtained across the whole of the community."

and

(TRC-2); p. 3, lines 12-14 of the report: "The study region was divided into concentric rings spreading outward from the former smelter to ensure a reasonably even spatial distribution of subjects, a point misunderstood by EPA."

vs.

(TRC-1); p. 3, lines 10-12 of the report: "Since a suitably matched control group was not identified, the study adopted a cross-sectional design relying upon regression analysis to test hypotheses regarding environmental lead: blood lead relationships."

U.S. EPA RESPONSE TO COMMENTS H 8:

There appear to be some major inconsistencies among these arguments. While it is useful to design a stratified sampling study so as to obtain representative samples within each stratum, it is essential that the stratification have some meaningful relationship to the hypotheses being tested. If there were only a desire to have uniform spatial representation of subjects, any number of alternate approaches could have been used, such as dividing the Madison County study area into census tracts and subtracts, or using existing political subdivisions such as separate cities, townships, and wards or taxation districts within the communities (in fact, no information about separate communities or neighborhoods is even included in the data set provided to EPA). Whether by intention or by inadvertence, stratifying the Madison County Lead Study area into concentric rings centered on the NL site has the effect of strongly stratifying the study by exposure gradient with respect to lead in soil and in household dust, and much more weakly with respect to building condition, lead paint, and sociodemographic variables. This is the only reasonable basis for Comment TRC-1, since a cross-sectional study designed to obtain representative samples from some portion of the study region regarded as the "control" area and from other parts of the study region designated as "target" areas must be divided up according to known or expected levels of exposure variables and of important covariates. While other geographic subdivisions of the study area would have allowed a better separation of the effects of soil lead from the effects of other lead sources and from some of the potentially confounding sociodemographic factors, such as those described in EPA's May 23, 1994 comments on the draft IEHR/IDPH report, the use of concentric rings was highly informative. If this stratification did not provide a basis for regression modelling in which the "control" areas were the more remote parts of the Madison County Lead Study, then the validity of that study for inference about children in Madison County must be brought into question. Our use of the distance stratification was based on what this approach to study design actually seems to have accomplished, rather than on its intended uses as described inconsistently in comments TRC-OBJ8, TRC-1, and TRC-2.

COMMENT H9 (TRC-OBJ9); p. 2, last 5 lines of the report: "... U.S. EPA's use of the default IEUBK Model, which ignores the real data gathered at the site in contravention of the instructions stated in the user manual, has numerous flaws and provides a misleading assessment of the potential benefits of soil lead remediation. We believe that the cleanup scenarios presented in this analysis provide a more realistic representation of the effects of soil lead remediation."

U.S. EPA RESPONSE TO COMMENT H9:

U.S. EPA made extensive and appropriate use of the data in the Madison County Lead Study, including significant limitations in study design, non-standard protocols for collection of soil and dust samples, and non-standard protocols in reporting household dust lead concentrations. The Guidance Manual notes the importance of collecting appropriate site-specific samples for use as input in the IEUBK model, a point which the commentors appear to have overlooked. As we will discuss below, the assessment of community-wide risk levels seriously distorts the intended application of the model to evaluate risk on a unit-by-unit basis. We agree that not all of the yards in the study area need to be remediated; however, highly elevated soil lead concentrations are heavily concentrated in the vicinity of the NL site, but also occur at a few other places in Madison County. Our analyses are directed towards setting remediation goals at these residential units.

COMMENT H 10 (TRC-3); p. 3, lines 20-31 of the report:

"... the soil lead/blood lead relationship was confounded by a large number of interrelated variables. When hierarchical regression was used to account for key interrelated parameters i.e., water lead, paint lead, condition of paint), it was shown that soil lead accounted for only 3% of the blood lead variance. In relation to other risk factors, the contribution of soil lead was considered to be quite small. For example, comparison of blood lead results across the soil lead <500 ppm vs. >500 ppm groups found only 1.4 ug/dl differential. In contrast, a marked blood lead differential was found across residences representing different levels of upkeep. Blood lead in 0 to 6 year old children ranged from 6 ug/dl when the residence was in good condition, to 8.2 ug/dl for a rating of fair condition, to 11.8 ug/dl for poor condition. Such findings lead to the conclusion that in this community, factors other than lead in soil have a more important impact on blood lead, in spite of the fact that soil lead levels ranged up to 3,000 ppm."

RESPONSE TO COMMENT H 10:

This comment intermingles and confuses a number of important technical issues in the statistical analyses and in their interpretation. To deal with the points separately:

(1) Soil lead is not a very strong predictor of blood lead because it is not usually the most proximate or immediate exposure medium for young children. Dust lead is a far better direct predictor of environmental lead effects on blood lead than is either soil lead or lead paint, since household dust is a medium to which almost all children are regularly exposed. Soil lead is a strong predictor of lead in household dust, and in the vicinity of the NL site is usually much more closely associated with dust lead than is lead paint. Even the IEHR/IDPH report demonstrates, in Table 10 of that report, that dust lead loading is by far the most significant predictor of blood lead (F=59.1[illegible]), followed by less significant modifiers for individual behavior (hours of outdoor play, F=24.13; child age, F=20.29), household characteristics (ethnicity, F=12.45; recent remodeling, F=9.89), and then distance (F=10.28) which is still highly significant (P=0.0015). (To explain the meaning of the term "F", statistical significance was often characterized by the value of a statistic for testing the hypothesis that the covariate has no effect on blood lead. The statistic reported by IDPH was Fisher's "F" statistic. Any value of F larger than about 4.0 indicated that there was a significant relationship between blood lead and the covariate.) EPA analyses, using a variety of hierarchical and stepwise regression modelling strategies, linear and nonlinear model specifications, find that virtually identical results can be obtained if distance is replaced by the logarithm of soil lead concentration. The failure to use dust lead in the hierarchical regression analysis in the IEHR/IDPH report is thus equivalent to a failure to include the total effect of soil lead on blood, whose primary manifestation is through the dust lead pathway. This omission is all the more puzzling because the role of soil lead as the primary predictor of dust lead, and therefore as an important indirect predictor of blood lead, is clearly demonstrated in the IEHR/IDPH report Table 12, Model 2. Table 11 in the IEHR/IDPH report shows that the hierarchical regression model reported there is seriously deficient, since all of the variables used in that model explain less variability in blood lead than does dust lead alone. The potential confounding of soil lead, paint lead, and dust lead is explored in the EPA

analyses using a variety of multivariate statistical methods, and is shown to be a relatively minor technical problem. Even if one accepts the validity of the soil lead, dust lead, and paint lead data in the Madison County Lead Study, the effects of these variables on blood lead can be substantially separated. The modest amount of confounding is a technical issue that can be reasonably resolved, since the Madison County Lead Study contains all combinations of houses with high soil lead and low soil lead, high dust lead and low dust lead, high paint lead and low paint lead, although not in equal proportions.

(2) The commentors present a breakdown of mean blood lead concentrations by separating soil lead concentration into two categories, <500 and >500 ppm. They also show breakouts of blood lead by house condition, and later (comment TRC-7) by ethnicity. This tends to distort the relationships, since soil lead, paint lead, house condition, and ethnicity are not independent of each other, and multivariate statistical methods are needed to understand the interrelationships. A variety of such methods were used in the EPA analyses. Bivariate (two-component) tables or figures can be informative, however, in suggesting underlying relationships. But, as EPA noted in its comments of May 23 and October 20, bivariate statistics alone are not adequate for understanding these relationships.

COMMENT H 11 (TRC-4); page 3, para. 2, bottom sentence: "Consistent with this is the results of an educational intervention in this community in which a marked blood lead decline was attributed to this intervention."

U.S. EPA RESPONSE TO COMMENT H 11:

The commentors show appropriate reserve in interpreting the reduction in blood lead levels attributed to educational intervention in the IEHR/IDPH report. The hypothesis that educational intervention produces short-term decreases in blood lead for children who reside in the household is plausible, but the followup study does not allow the hypothesis to be tested, nor the size of the reduction to be estimated, in the absence of any control group.

COMMENT H 12 (TRC-5); page 5, para. 3 of the report:

"... the majority of blood lead exceedances in this community are in cases where soil lead is low (less than 500 ppm)."

U.S. EPA RESPONSE TO COMMENT H 12:

The statement is correct, but highly misleading. Soil lead is low in the overwhelming majority of Madison County residences, but other sources such as lead-based paint and lead in tap water are high in some of these residences. It is hardly surprising that elevated blood lead concentrations should occur in some of these houses, which taken together constitute a majority of the total number of cases of elevated blood lead. As shown in Table 1 (attached), there is a systematically increasing relationship between the incidence of elevated blood lead and soil lead. More detailed analyses show that this relationship persists even after adjustment for other environmental lead variables and for a variety of behavioral and sociodemographic covariates and modifying factors.

COMMENT H 13 (TRC-6); page 4, lines 5-10 of the report:

"... the NHANES III dataset ... indicates that 16.4% of childhood (1 to 5 year old) blood lead values exceed 10 ug/dl in urban areas of less than one million in population. This correspondence with Granite City blood lead results suggests that if a problem does exist at Granite City, it is best attributed to the same types of lead source that are typical of the urban environment (e.g., old housing containing dilapidated lead paint; historic lead fallout from fuel combustion)"

U.S. EPA RESPONSE TO COMMENT H 13:

See response to comment H 1 (TRC-OBJ1). There is a **localized** soil lead exposure problem, associated with historical emissions from the NL site, with an incidence of about 25 percent elevated blood leads in preschool children. The more distant parts of Madison County, with an incidence of elevated blood lead of about 10 percent, may be more typical of older urban areas. However, isolated locations exist elsewhere in Madison County where there is soil lead contamination from battery chips and other waste materials specific to this site. The comparison of the entire Madison County study area to a national average (which is still higher than is desirable from a health perspective) is an attempt to dilute a local and site-specific problem by averaging this area with other areas that have much lower lead exposures.

COMMENT H 14 (TRC-7); page 4, lines 10-14 of the report:

"It should be noted that in the Granite City dataset, race had very little impact on blood lead, with the mean for white and non-white children not being statistically different. This contrasts with the NHANES III dataset where urban non-whites had substantially higher blood lead than did urban whites. It is possible that this indicates similar SES status for Granite City whites and non-whites since at Granite City, SES was a key determinant of blood."

U.S. EPA RESPONSE TO COMMENT H 14:

This comment presents another incomplete bivariate assessment. The majority of non-white preschool subjects in the Madison

County Lead Study resided at some distance from the NL site, where soil lead and dust lead concentrations were typically much lower than in the vicinity of the NL site. After statistical adjustment for environmental lead exposure and for a large number of individual behavioral covariates and sociodemographic characteristics, with particular emphasis on indicators of SES, EPA analyses found that race or ethnicity was among the most important of the non-environmental covariates. Non-white children typically had higher blood lead concentrations than non-white children, everything else being equal, a finding consistent with almost all earlier reports (e.g. Stark et al., 1982; Weitzmann et al., 1993; Aschengrau et al., 1994) as well as with NHANES III, and with the most credible of the analyses reported in the IEHR/IDPH report in Table 10.

COMMENT H 15 (TRC-8); p. 4, para. 2, lines 8-15; p. 5, lines 6-10 of the report:

"... the model overpredicted blood lead concentrations by nearly 2 fold in the soil lead subgroup that was greater than 1000 ppm (7.1 actual; 13.7 predicted). Additionally, the percentage of children with blood lead above 10 ug/dl was overestimated by a large factor in this subgroup. A similar situation occurred in the 501 to 1000 soil lead subgroup, although the model overprediction was not as large (37%). In the lower soil lead groupings (0 to 250 ppm, and 251 to 500 ppm) the model-predicted blood lead was reasonably close to that actually observed, although in the lowest subgrouping, the model underpredicted by 27%. ... The trend in Table 1 [of the TRC report] is that at low soil and dust lead concentrations (i.e., below 500 ppm), the model provides a good estimation of childhood blood lead. However, with increasing soil/dust lead concentration above 500 ppm, the model becomes increasingly overpredictive, such that for a significant percentage of young children at Granite City (29%), the default version of the model is inappropriate."

U.S. EPA RESPONSE TO COMMENT H 15:

U.S. EPA noted some deviations between observed blood lead and blood lead predictions using the IEUBK model. A large number of graphical and statistical comparisons have been made in order to understand why these deviations had occurred. A detailed report is being prepared, but the results of the EPA analyses include:

(1) the deviation between observed and predicted blood lead concentrations was predicted better by **reported** dust lead concentration than by any other variable, including soil lead;

(2) Very large deviations (predicted - observed > 25 ug/dl) occurred for about a dozen children who lived in households with extremely high **reported** dust lead concentrations (> 6000 ppm), which are believed to represent dust samples that have been

biased substantially upward by mathematically averaging the dust sample with a sample of large lead paint chips;

(3) Blood lead was also overpredicted among all children with **reported** dust lead concentrations between 1750 and 6000 ppm, but to a much smaller extent (< 25 ug/dl), since some but probably not all of the dust samples were also somewhat contaminated by inclusion of large paint chips;

(4) On average, the IEUBK model overestimated blood lead concentrations slightly for reported dust lead concentrations in the range of about 750 to 1750 ppm, which is believed to represent dust samples whose lead content has been biased upward to a lesser extent than the samples in (2) and (3);

(5) Blood lead was accurately predicted by the IEUBK model for reported dust lead concentrations below about 750 ppm, which corresponded roughly to reported soil lead concentrations < 900 ppm;

(6) Apart from the 10 to 12 children living in residences with very high dust lead concentration, there was only the expected weak dependence of observed blood lead on the behavioral and sociodemographic variables, so that the deviation between observed blood lead (which depended on these covariates) and predicted blood lead (which did not depend on these covariates) showed a weak relationship to, but no systematic bias from:

Child's age
Hours of outdoor play
Hours of play on the floor
Mean number of cigarettes smoked by adult residents each day
Parental education
Household income group

(7) On average, the IEUBK model underestimated blood lead concentrations in non-white children by about 1.2 ug/dl;

(8) The deviation between observed and predicted blood lead increased slightly for buildings in worse condition, but showed no systematic deviation apart from the children with very high dust leads;

(9) The large deviations between observed and predicted blood lead did not depend on the interior or exterior lead paint index (average of the product of XRF loading and paint condition);

(10) There was some tendency for the model to overpredict blood lead when the average product of interior XRF lead loading and paint condition exceeded about 5 to 10 mg Pb/cm^2, which

is consistent with deviations attributable to paint-biased dust samples;

(11) Apart from the 10 to 12 children with very high reported dust lead concentrations, the model accurately predicted blood lead for dust lead loadings less than 5 mg Pb/m^2, and overpredicted slightly at dust lead loadings greater than 5 mg Pb/m^2.

(12) Given the fact that previous activities to educate Granite City residents on lead sources and how to minimize exposure to these sources has modified some residents' behavior, the model should overpredict blood lead somewhat in Granite City since educational activities have introduced a potential low bias to blood lead results.

(13) We would like to emphasize the fact that the soil lead and dust lead data reported in the IEHR/IDPH study and used in EPA reanalyses of the data represent valid measurements that can be used in a wide variety of empirical modeling exercises. These data are predictive of blood lead in pre-school children, and therefore can be useful in other risk estimation activities. However, there are some important or potentially important differences between these soil lead and dust lead data and the analogous measurements intended as input to the IEUBK Model, as indicated in the above remarks, that were apparently overlooked by the commentors.

COMMENT H 16 (TRC-9); p. 4, last para.:

"... The model predicts a soil lead/blood lead slope of 7.48, which is far above that actually seen (1.70). This overprediction of the slope leads to the false conclusion that blood lead is very sensitive to changes in soil lead such that if soil lead were remediated, blood lead levels should fall dramatically. The Urban Soil Lead Abatement Project (Baltimore, Cincinnati, Boston) indicated that very little benefit could be found after remediation of soil lead (e.g., Weitzman, 1993), which supports the concept of a low soil lead/blood lead slope."

U.S EPA RESPONSE TO COMMENT H 16:

The total relationship between blood lead and soil lead usually includes several assumptions about the role of relationship of soil lead to dust lead, about the rates of ingestion of soil and dust, and about the absorption of lead from ingested soil and dust. Use of a composite slope factor as suggested by the commentors conceals these implicit assumptions, whereas the IEUBK Model makes the assumptions transparent. Our analyses of the Madison County Lead Study data suggest that the contribution of **reported** soil lead to **reported** dust lead may be much lower near the NL site than the standard model parameters, but this conclusion may be biased because the dust and soil sampling and reporting protocols appear to differ from those that were used in developing and calibrating the IEUBK model. An assessment of the effect of remediation may be made in at least two different ways. The approach that most closely matches the USLADP is to assume that changes in environmental lead exposure are followed in children who had been previously exposed to higher concentrations. The simulations cited in the Guidance Manual show that it takes about two years to achieve blood lead concentrations similar to those achieved in children two years older who had grown up in the cleaner post-remediation environment. The decrease in blood lead in the second post-remediation year and subsequent years occurs because the internal body burden of lead stored in the skeleton is gradually eliminated, and because house dust is not recontaminated when a primary source of lead in soil is eliminated. This appears to have occurred in the Boston component of the study (Aschengrau et al., 1994), and in the major CERCLA remediation project near Kellogg, Idaho (Von Lindern et al.,1994), but not in the other USLADP projects which did not achieve effective control of contamination from other sources. A better indicator of remediation effectiveness is the blood lead concentration of children who are born in or move into remediated housing while very young. The "slope factor" could at most be used to compare only children who have grown up in remediated and non-remediated housing, assuming these were equivalent in every way, and could not be used to estimate blood lead in children when the post-remediation housing has different properties of soil or dust lead transport, intake, or absorption. Some site-specific adjustment of the IEUBK model parameter for soil-to-dust transport was evaluated based on the environmental data from the Madison County Lead Study, but further post-hoc calibration is not warranted due to uncertainties about the soil lead and dust lead data used as input.

COMMENT H 17 (TRC-10); p. 5, lines 12-17:

"The most likely explanation for the overprediction may be decreased absorption of lead from soil and dust at higher lead loadings. This concept is consistent with a variety of literature sources (e.g., Sherlock 1986; Bushnell, 1983) and is more plausible than other potential explanations (children contact less soil or house dust if it contains high lead; shift in lead internal distribution away from blood at higher intake)"

U.S. EPA RESPONSE TO COMMENT H 17:

There is no biological or physical basis, using site-specific soil or dust samples from the Madison County Lead Study, to confirm the commentors' speculation that absorption of lead from these media shows the sharp dependence on soil lead concentration suggested in the TRC report. Known differences between soil and dust lead sampling and reporting protocols used in the Madison County study and protocols used in the studies on which the IEUBK Model parameters were based can account for differences between observed and predicted blood lead. Other possibilities include differences in the amount of soil and dust ingested by children in the study, or differences in the relative proportion of soil to dust ingested. In fact, differences between observed and predicted blood lead are relatively small once the 10 to 12 cases with the largest dust lead concentrations (probably inflated by inclusion of lead paint chips) are excluded from the comparison. Additionally, U.S. EPA has observed that residents living near the smelter (higher lead concentrations) appear to have modified their children's behavior to reduce exposure to environmental lead, moreso than those living further from the smelter. This phenomenon is clearly one of the reasons for the overprediction of blood lead at higher soil concentrations.

COMMENT H 18 (TRC-11); p. 5, lines 20-27 of the report:

"The model was iterated using different absorption coefficients until a good fit was achieved for each soil lead subgrouping. Table 2 [of the TRC report] shows the back-fitted absorption coefficients that provide the best fit for several soil lead subgroupings. While the model default value of 30% soil absorption is appropriate for the 251-500 ppm group, lower absorption coefficients are required for fitting the model to actual data in higher soil lead groupings. The relationship between absorption coefficient and composite soil/dust lead concentration approximates a straight line with a negative slope .... (Figure 1 [of the TRC report])."

U.S. EPA RESPONSE TO COMMENT H 18:

Plausible alternative explanations based on site-specific information were discussed in Responses to H 7, 8, 9 (TRC-8, 9, 10). In addition, there is no biological basis for the straight-line relationship, and backfitting grouped blood lead and soil/dust lead data rather than individual data is inappropriate. The negative straight line relationship (% absorption = 35.4 - 0.02 * TWA, where TWA is a time-weighted average soil and dust lead composite concentration) implies that lead absorption is negative when the composite soil/dust lead concentration exceeds 35.4/0.02 = 1770 ppm, which is absurd.

COMMENT H 19 (TRC-12); p. 6, lines 1-8 of the report:

"Our approach allows for house dust concentrations to exceed soil lead concentrations as is often the case at Granite City. The likely explanation for this differential is that interior lead sources (i.e., flaking interior paint) are a key source of dust lead. Thus, when soil lead is abated and nothing is done about interior lead paint sources, the house dust lead concentration will change by only that fraction contributed by soil lead. By adjusting dust lead by 0.7 times the decrease in soil lead, we are being faithful to the USEPA default for soil lead contribution to house dust while not ignoring other factors which contribute to house dust."

U.S. EPA RESPONSE TO COMMENT H 19:

As noted in Responses TRC-8, 9, 10, the reported dust lead concentrations are probably inflated by inclusion of large lead paint chips that have little capability of adhering to the child's hands. We attempted to implement the commentors' approach by calculating an estimated non-soil contribution for each household, estimated non-soil dust lead = dust lead concentration - 0.7 X soil lead concentration, but in many cases this was a large negative number, which is not physically possible. Grouping into ranges of soil and dust lead does not eliminate the negative values that occur when dust lead is low and soil lead is high. A workable alternative is to use a regression model of the form,

estimated dust lead = a + b * soil lead concentration + c * interior lead paint index,

so that

b * soil lead concentration = estimated soil contribution to dust lead

and

c * interior lead paint index = estimated paint contribution to dust lead

and

a = all other contributions to household dust lead.

The standard assumption in the IEUBK Model is that b = 0.7. The regression approach EPA used produces positive values of the soil lead coefficient b and paint lead coefficient c, so that a physically meaningful estimate of their contributions can be made on a house-by-house basis.

COMMENT H 20 (TRC-13); p. 6, 7-12 lines from bottom:

"The influence of soil lead remediation on the overall population geometric mean is predicted to be minuscule, which is consistent with the fact that these cleanups would accomplish very minor reductions in population geometric mean soil and dust leads. Since the vast majority of households have soil and dust concentrations below 500 ppm, remediation of relatively few households at the top of the distribution shifts the overall exposure concentration little."

U.S. EPA RESPONSE TO COMMENT H 20:

Again, the issue is that there is a relatively localized problem in which high soil lead concentrations contribute most of the lead in household dust, which is predictably related to an increased likelihood that pre-school children living in that residence will have elevated blood lead concentrations. In that part of Madison County in the vicinity of the NL site, most yards have elevated soil lead and most houses have elevated dust lead. The commentors' use of community-wide statistics obscures the fact that elevated blood leads are much more frequent near the NL site and in the "downwind" direction, and therefore dilutes the effects that soil lead remediation will have on that part of the population. The individual residential housing unit is the appropriate scale for assessing lead exposure, and therefore for assessing the effectiveness of lead abatement. U.S. EPA would like to stress that, consistent with the consensus of the experts for the City of Granite City, the PRPs, and U.S. EPA (February 1995), residential soil remediation will have long-term benefits (years) for the community, including future residents, and may have short-term benefits (months) for the current residents.

COMMENT H 21 (TRC-14); p. 7, lines 8-16 of the report:

"... many children have elevated blood lead in spite of being surrounded by relatively low soil lead (below 500 ppm) .... soil remediation will have little impact at homes whose house dust concentration clearly exceeds the soil lead concentration. Interior sources (e.g., lead paint) likely outweigh soil lead in such cases. The database contains 120 cases where house dust lead exceeds soil lead by 200 ppm or more, with 83 of these cases having at least a 500 ppm differential. Blood lead exceedances [of 10 ug/dl] are a common occurrence in these cases (23%), and these cases will not be materially improved by soil lead remediation."

U.S. EPA RESPONSE TO COMMENT H 21:

The potentially biasing effects of the dust lead reporting and soil lead sampling protocols should be kept in mind when assessing these data. As noted above, dust lead concentrations and dust lead loadings are the most predictive environmental lead indices for blood lead exceedances. However, it is possible to use the Madison County Lead Study data to test the commentors' hypothesis that interior sources such as lead-based paint outweigh soil lead when dust lead is high. The relative contributions of soil lead and paint lead to dust lead can be assessed using the regression approach discussed in Response to H 19 (TRC-12). EPA calculated these contributions, and counted the number of residences in each distance ring in which the estimated soil lead contribution to dust lead in that residence exceeded the estimated paint lead contribution to dust lead. In the majority of residences within about one half mile from the NL site, the soil contribution exceeded the paint contribution. In those cases where the current soil lead concentration is sufficiently high to produce an unacceptably high risk of an elevated blood lead concentration, effective soil lead remediation should be the first primary lead exposure prevention action. However, low-cost actions to control lead exposure before soil remediation is carried out (such as parental education and lead paint stabilization) may also be useful interim measures that can be temporarily effective.

COMMENT H 22 (TRC-15); p. 7, 2-12 lines from bottom:

"The Madison County Lead Exposure Study points out the numerous confounding factors which affect the relationship between distance from the smelter and blood lead ... EPA's assessment does not clearly differentiate between lead sources and provides no indication of their quantitative importance ..."

U.S. EPA RESPONSE TO COMMENT H 22:

One of the foremost goals of EPA analyses described in the draft report was to identify the quantitative contributions of lead sources to different exposure pathways for children, and to quantitatively assess whether potential confounding with other lead sources, individual or demographic factors altered estimates of these relationships. In general, the exposure of children to lead in soil occurred largely indirectly through the dust lead pathway, but with a detectable direct soil lead exposure as well. Confounding with sociodemographic factors was assessed quantitatively and found to be present, but at relatively modest levels that had little effect on soil and dust lead estimates. Lead paint was found to be an important component of household dust, but generally made a much smaller contribution to dust lead than did soil lead in housing units close to the NL site, although such interpretations are complicated by the probable inflation of the role of lead paint in dust lead concentrations by inclusion of large paint chips in some reported dust lead concentrations.

COMMENT H 23 (TRC-16); p. 7, bottom 2 lines:

"... EPA's use of the IEUBK Model is flawed by arbitrarily assigning a default value for house dust when actual site-specific house dust data are available."

U.S. EPA RESPONSE TO COMMENT H 23:

In view of the concerns we had about the applicability of reported dust lead data as input for the IEUBK Model, a scientifically responsible assessment required some additional sensitivity analyses assuming standard soil-to-dust contributions, as well as other values using site-specific data.

COMMENT H 24 (TRC-17): p. 8, top 2 lines:

"The Model performs poorly for a large percentage of cases when model defaults (as used by EPA) are incorporated."

U.S. EPA RESPONSE TO COMMENT H 24:

Except for a number of cases where reported dust lead concentration were very high, producing excessively high predicted blood lead concentrations, model performance was good, and on average predictions were very close to observed blood lead for soil lead less than 900 to 1000 ppm and dust lead < 700 to 800 ppm.

COMMENT H 25 (TRC-18); p. 8, para. 3:

"This correlational analysis, which focuses upon distance from the former smelter, is confounded by a variety of factors ... year residence built, building condition, household income and education level, and home ownership confound the relationship between soil lead and blood lead as judged by distance ... several of these factors would suggest that paint lead could become a stronger source of lead closer to the former smelter, in spite of the fact that paint lead levels are not actually correlated with distance ... building condition worsens with proximity to the smelter ... (parental income, parental education, number of children per household) are all adversely affected with increasing proximity to the former smelter. Thus, the degree of parental supervision and awareness needed to prevent children's interaction with paint lead sources (e.g., gnawing on painted surfaces) appears to decline near the smelter. ... These factors indicate that although paint lead levels are not correlated with distance, the degree of lead uptake would still be expected to increase with increasing proximity to the former smelter. The likelihood that paint lead is substantially contributing to the blood lead vs. distance correlation is not recognized by EPA."

U.S. EPA RESPONSE TO COMMENT H 25:

The following concerns the relationship of soil lead to distance from the NL Site:

The relationships among blood lead, dust lead, and lead sources in soil and paint have been among the foremost concerns in EPA's reanalyses of the Madison County Lead Study. A very clear role has been identified for deteriorating interior lead-based paint as an important source of lead in household dust, but lead paint is clearly secondary to soil lead in the areas closest to the NL site where most high soil lead concentrations are found. Paint lead may be a more important contributor to dust lead in outlying parts of Madison County where soil lead concentrations are typically much lower, although high soil lead concentrations are also found in a few places in the outlying areas, attributable to lead paint or to other sources such as use of waste materials for fill or for street repair. These cannot be confirmed since IDPH has not provided us with any information about the location of these residences. It is likely that these few exceptional cases (4 out of 351 units) are found in places such as Venice Township or Eagle Park Acres.

U.S. EPA has also evaluated the role of location (as measured by distance from NL) as a potential confounding factor. At any given location (ring or group of adjacent rings surrounding the site), there are some houses with higher levels and some with lower levels of almost any other measured variable in the study: dust lead, paint lead, parental education and income. Of all the variables in the study, none is seriously confounded with distance from the NL site except for soil lead concentration. The range of soil lead concentrations in any ring is relatively small, so that soil lead and distance are relatively highly correlated with each other. The average soil lead in each ring is very nearly inversely proportional to the distance of the ring from the smelter. In this regard, the soil lead distribution around the NL site looks very similar to every other lead smelter community we have studied.

U.S. EPA has analyzed the relationship between soil lead and the only other plausible source of elevated lead concentration in residential yard soils, deteriorating exterior lead-based paint. We found that there was a consistent contribution of exterior lead-based paint to soil that was approximately the same at any distance from the NL site. Similar results were obtained by several different analytical methods (linear and non-linear regression, structural equations modelling). The condition of the building was used as a covariate in many of the analyses, as were other sociodemographic variables, and their interactions were tested. When the estimated contribution of exterior-lead-based paint and building condition were subtracted from the observed soil lead concentration, there remained a large positive fraction of soil lead at most residences that was not explained by lead paint or by building condition. This component could be reasonably attributed to historical deposition of airborne particles emitted by the smelter and dust particles blown off the site. Neither the building condition nor the background term were ever statistically significant. The best-fitting model (smallest residual variance) was a very simple linear model, fitted in log form:

Soil lead concentration = (1333 / distance) + 7.79 CXRFOAV, where distance = ring number 1 through 10, and where CXRFOAV is the average of the exterior XRF lead paint loading times the exterior paint condition. Since CXRFOAV never exceeded 62.3, and was usually much smaller, the lead paint contribution was always less than 500, usually much less, the remaining term which depended on distance was dominant near the NL site. There was little evidence of confounding between distance and exterior paint. We conclude that most of the lead in soil near the NL site must be attributed to some processes by which lead is transported from the smelter to the surrounding yards. This implies that much of lead in soil near the NL site will have properties similar to those of other former smelter communities we have studied: high bioavailability and ready transport from surface soil into the household dust.

The following concerns the relationship of soil lead, interior lead Paint, and building condition to dust lead:

Most lead experts agree that household dust is a very important medium for childhood lead exposure, and is likely the primary exposure pathway for lead in soil and for lead in interior lead-based paint. Ingestion of exterior dust from soil is nearly as important as the indirect pathway from soil through household dust. Direct ingestion of large flakes or chips of deteriorating interior lead paint can have catastrophic consequences when it occurs, but it would appear that direct ingestion of paint chips is a highly unusual circumstance in Granite City. Most children are likely to obtain most of their interior lead paint intake from ingestion of fine particles adhering to the child's hands during normal activities on floor, carpets, or furniture contaminated by lead dusts, with paint as only one of the lesser sources contributing to house dust, compared to track-in of soil and deposition of airborne particles.

There have been many assertions that most of the lead in household dust is attributable to interior lead paint. Our analyses point in a very different direction. In fact, even Table 12 in the IDPH report, finds that lead in soil and lead in paint make contributions that are nearly equal in statistical significance. However, the actual contribution of soil to dust is greater near than NL site than is the detectable contribution of interior lead-based paint because of the greater measurement uncertainty in soil lead concentrations compared to exterior paint loadings. The contribution of soil lead to household dust lead is generally **much** larger than the paint contribution in rings 1 through 4 or 5, and on average comparable further away from the site.

U.S. EPA has analyzed the relationship between dust lead and the only other plausible source of elevated lead concentration in household dusts, deteriorating interior lead-based paint. U.S. EPA found that there was a consistent contribution of interior lead-based paint to dust that was approximately the same at any distance from the NL site. Similar results were obtained by several different analytical methods (linear and non-linear regression, structural equations modelling). The condition of the building was used as a covariate in many of the analyses, as were other sociodemographic variables, and their interactions were tested. When the estimated contribution of interior-lead-based paint and building condition were subtracted from the observed dust lead concentration, there remained a large positive fraction of dust lead at most residences that was not explained by lead paint or by building condition. This component could be reasonably attributed to lead in yard soil that was transported into the house. The yard soil contained lead from the smelter or waste pile, along with some exterior lead paint particles. Both soil lead and deteriorating interior lead paint were highly significant predictors of dust lead concentration. The building condition was a statistically significant predictor of household dust lead in most of the models we tested, but much less significant than the soil or paint "source" terms. The background term was positive but not statistically significant in most models we tested. The best-fitting model (smallest residual variance) was a very simple linear model, fitted in log form:

Dust lead concentration = (0.385 Soil lead) + 94.5 CXRFIAV + (82.7 Building condition)

where building condition was coded 1 through 3, and where CXRFIAV is the average of the interior XRF lead paint loading times the interior paint condition. Since CXRFIAV never exceeded 39.4, and was usually much smaller, the lead paint contribution to household dust was often small, but sometimes large. U.S. EPA also tested distance from the site as a covariate. When distance was included in the model, distance usually had a statistically insignificant effect on dust lead, apart from its relationship to physically meaningful source terms such as soil lead and interior paint lead, and to building condition as a modifier of effect. In fact, interactions of building condition with soil lead or with distance were also not statistically significant. Interactions of building condition and interior lead paint with distance were marginally significant in some models we tested.

Any conclusions about the role of interior lead paint in house dust must be tempered by the fact that some of the dust lead concentrations reported contain inflated levels of lead, since the reported dust values were mathematical composites of the concentrations of fine sieved particles and of larger particles including large paint chips. The large paint chips would not be expected to adhere to a child's fingers or hands. Since the amount of lead in these chips would not be expected to be predictive of the lead in dust that most pre-school children transfer to their mouth during normal play, these large chips have generally been excluded from dust sample concentrations reported in other studies.

The following concerns the fraction of lead in dust attributable to lead in soil and paint:

U.S. EPA used the prediction equation for lead in household dust to estimate the fraction of dust that was attributable to soil at each house:

Soil fraction = (0.385 Soil lead) / (Predicted dust lead concentration)

Paint fraction = (94.5 CXRFIAV) /(Predicted dust lead concentration).

Soil lead is the dominant contributor to lead in household dust near the NL site. This implies that much of lead in dust near the NL site will also have properties similar to those of other former smelter communities we have studied: high bioavailability and ready transport from household surfaces into the child's mouth.

One way to visualize the relative importance of lead in soil is shown in Figure 1. Here, U.S. EPA has plotted the percentage of housing units for which the estimated soil lead fraction of house dust lead is greater than the estimated paint lead fraction of house dust lead. Note that this decreases from a maximum near the NL site at ring 1 to a minimum at ring 9, but is greater than 50 percent from rings 1 through 8. **In other words, lead from soil appears to make a greater contribution to household dust lead than does interior lead paint in the majority of houses within about one mile of the NL site.** Even this analysis may overstate the importance of paint lead in the Madison County study, since the reported dust lead concentrations may be inflated by the inclusion of large paint chips.

The following concerns confounding of environmental and sociodemographic factors in child blood lead concentrations:

"Confounding" is a term that is widely used in epidemiology and other observational sciences. Confounding occurs when some third variable or factor is related both to the outcome or response being studied -- in this case, childhood blood lead -- and to the nominal cause of the outcome, such as lead in dust or soil. As noted in our "Preliminary Assessment" of October 1994, several factors appear to match the decline in mean blood lead with increasing distance from the NL site, including decreasing soil lead and dust lead, decreasing housing age and deterioration, increasing parental education and income. These are potential confounding factors.

Confounding is a **potential** problem in this study. Is the problem real? U.S. EPA has evaluated quantitatively the amount of confounding, to the extent that it can be defined internally from the data in the study, in a draft report in preparation. Confounding has both a conceptual aspect and a technical aspect. Conceptually, confounding can occur as a result of failure to design an appropriately representative sample. Some of the confounding in the Madison County Lead Study could have been avoided by better design of the study. When the confounding is not avoided by design, then some statistical methods may allow quantitative identification of potentially confounded variables. In linear statistical models, confounding can be identified by statistical methods that identify a technical condition known as collinearity. The collinearity diagnostics among the 30 most plausible predictors have shown that collinearity as a serious problem only occurs under three conditions:

(i) when the logarithms of dust lead loading, dust lead concentration, and total dust loading are all used in a regression model, there is a perfect collinearity as shown above;

(ii) the logarithm of the shifted variable CXRFIAV, the mean of the product of paint condition and XRF lead loading on interior surfaces, is highly correlated with the logarithm of the mean XRF, and using both in a regression model causes a loss of information efficiency;

(iii) the logarithm of soil lead is highly correlated with the logarithm of distance (geometric mean soil lead in each ring is nearly inversely proportional to distance), and the use of both log of soil lead and log of distance in the same equation should be avoided. If these combinations are avoided, then there are no severe collinearities and the effects of most other predictors or covariates can be estimated separately in joint regressions with only a modest degree of variance inflation.

Household covariates are responsible for part of the variation in blood lead, and including demographic covariates such as race or ethnicity, parental education or home ownership in a model will generally reduce the unexplained variance in blood lead. These variables are not so highly correlated with soil lead, however, and are therefore weak confounders of the relationship.

In a non-technical sense, there is only a slight to moderate amount of confounding between soil lead and blood lead. For example, there is only relatively modest confounding with dust lead. Within each distance or ring, there is some variation in soil lead concentrations. However, for any soil lead concentration, there are housing units with both lower and higher dust lead concentrations and children with both higher and lower blood leads. Therefore, the interfering effects of dust lead differences (using dust lead as the closest predictor of blood lead on the pathway, and as an indirect exposure pathway from soil lead to blood lead) can be minimized. Likewise, sociodemographic factors or building condition can be related to both blood lead and soil lead, since a range of sociodemographic variables is found at almost all levels of soil lead or dust lead. Regarding parental suervision, U.S. EPA has observed that many residents living closest to the smelter are well aware of the lead problems, and, contraty to the commenter's inference, appear to have actively modified their children's behavior to reduce exposure to environmental lead.

In summary, extensive diagnostic analyses of a variety of statistical models find that confounding is a worrisome but not insurmountable problem in estimating separate effects of lead in soil, dust, and paint. Careful analyses of the Madison County data set can adequately characterize the typical contributions of lead in paint to soil, the contributions of lead in soil and paint to lead in household dust, and the separate contributions of soil lead and dust lead to blood lead.

COMMENT H 26 (TRC-19); p. 8, last three lines, and p. 9, first two lines:

"... soil lead is a major factor in elevating children's blood lead within these rings since only small changes in percent blood lead exceedances are seen ... regression of percent blood lead exceedances in rings against the corresponding soil lead levels is not significant."

U.S. EPA RESPONSE TO COMMENT H 26:

The analyses presented by the commentors appear to be completely inconsistent with their comments H 25 (TRC-18), since these analyses use percentage of elevated blood lead within each distance ring as if all children in the ring were identical with respect to age, other environmental factors besides soil lead, behavioral factors, and sociodemographic factors. A logistic regression analysis using dust lead as the proximate lead exposure indicator, individual covariates for each child, and blood lead exceedances coded as 0 or 1 for each child, would have been the correct approach, as in the EPA report in preparation. The results are very similar to those of the blood lead and dust lead regression models, with dust lead the most significant predictor of blood lead exceedances of 10, 15, or 20 ug/dl, and soil lead the most significant predictor of dust lead. The regression model fitted in the TRC report does not even appear to have been weighted for sample size or variance of the percentage.

COMMENT H 27; p. 9, lines 19-21 of the report:

"... applying model defaults for house dust that are lower than the actual house dust data, EPA produces a reasonable fit, but one that has no basis in reality or scientific principles."

U.S. EPA RESPONSE TO COMMENT H 27:

U.S. EPA has expressed some concerns that the soil lead and dust lead concentrations reported to us differ in some ways from those used in the studies on which the IEUBK Model is based. There is some possibility that the soil leads are somewhat lower than those that would have been obtained if perimeter or dripline soil samples had also been used for a yard average concentration, and that dust lead samples are higher (and is some cases, much higher) than would have been obtained if the large particles containing paint chips had not been averaged with the sieved fine dust sample. The soil lead concentrations appear to be less capable of distortion, and were used as received. The dust lead concentrations seemed more capable of distortion by the reporting protocol, so we ran models using the reported dust lead concentrations, as well as the estimated concentrations ranging from 29 to 70 percent of the soil lead concentration. The user of any mathematical model such as the IEUBK Model needs to be appropriately skeptical of the quality of input data, as noted in the Guidance Manual, and in view of our concerns about the applicability of the dust lead data as input for the IEUBK Model, the sensitivity analyses are scientifically appropriate.

COMMENT H 28 (TRC-21); p. 9, bottom para., first 8 lines of the report:

"The assumption that the Granite City environmental lead data can be described simplistically as house dust lead being 70% of soil lead is a significant error. ... in numerous individual cases, dust lead levels far exceed the corresponding soil lead levels. Thus, while soil lead may influence house dust lead, other interior sources (e.g. lead paint) also play a fundamental role in driving dust lead."

U.S. EPA RESPONSE TO COMMENT H 28:

This comment seriously mis-states the use of the soil-to-dust contribution parameter. The correct interpretation is that, on average, the soil lead contribution to household dust lead concentration is 70 percent of the soil lead concentration. The actual house dust lead concentration may be highly variable, and includes a lead paint contribution, an air lead contribution, a contribution from activities in the home that generate lead such the manufacture of lead solders or lead bullets, use of battery casings for heating or in "cottage industry" recycling, secondary exposure to dusts brought home from the workplace on clothing, shoes, and skin, and historic lead dust deposits that may still exist in the house in non-cleaned areas such as the attic or HVAC systems.

Unfortunately, the dust lead data reported to us may have been artificially inflated by including paint chip samples in some (perhaps many) of the calculated dust concentrations. In view of these input uncertainties, additional sensitivity analyses were carried out. The analyses suggested that the assumption of an underlying 70 percent soil contribution may be useful, in view of unresolved uncertainties about comparability of input data to other studies.

COMMENT H 29 (TRC22); p. 9, last para., last 12 lines; and p. 10, top 3 para.:

... an overly simplistic and incorrect model specification (house dust is 70% of soil lead with no significant interior sources) is introduced. ... the benefit of soil-lead remediation is substantially overpredicted by EPA's default back-calculation approach. ... We used a site-specific, non-default approach ... data from each household was run through the IEUBK Model (batch mode) ... assumed that 70% of the soil lead concentration is contributed to house dust lead, and that there are other interior sources that provide the remainder of the actual house dust lead measured. ... soil lead remediation was modeled to remove that fraction of the house dust lead that it is theoretically responsible for, while leaving in place that contributed by other sources ... the best approach is still to run remediation scenarios in the batch file mode in which actual house dust lead concentrations can be adjusted downward based upon the anticipated benefits from soil remediation."

U.S. EPA RESPONSE TO COMMENT H 29:

While individual household-level environmental data may be used to determine some site-specific parameters, it is not appropriate to limit the analyses to only those residences for which data are available. The housing units in the 1991 Madison County Lead Study constituted only a sample of the total number of housing units then occupied by pre-school children. Other housing units may be occupied by young children in the future, and even the same units may be occupied by residents whose residential uses and occupational patterns may be sufficiently different from those of the 1991 residents to cause very different dust lead concentrations from the same soil and paint lead sources, so that a more general approach may be needed. Standard model parameters are used to carry out risk estimation for generic housing units in the community.

One of the main problems in **any** use of the reported dust lead concentrations from the Madison County Lead Study in setting soil lead remediation goals is that they are likely to include some fraction of large lead paint chip samples, which may have very large lead contents and thus overstate the lead paint contribution to house dust lead, possibly even by orders of magnitude.

In order to assess the commentors' proposed method, additional analyses were performed by EPA using reported individual household dust concentrations. It was necessary to use other methods than those suggested by the commentors to infer soil and non-soil contributions to house dust, since the difference between the reported dust lead and 70 percent of the soil lead was often negative. EPA methods were based on regression estimates of paint and other non-soil background components of dust lead, which avoids some of the problems encountered in implementing the commentors' approach. Estimates of the effect of soil lead remediation were obtained. The risks of elevated blood lead were often larger because of the large contribution of the non-soil background, with a corresponding increase in the risk reduction benefit expected from soil lead remediation. The exact magnitude depends on assumptions made about non-soil background contributions. These are discussed in a forthcoming report.

RESPONSES TO COMMENTS

Memo from Maurice LeVois to Tom Long, July 21, 1994

COMMENT H 30; (Comment ML1, p. 1; Sec. 1.2):

"The term 'control group' implies that there is a clear definition of what, how, and why we are controlling by design or analysis strategy. In this case Pontoon Beach was different with respect to SES and living conditions ... They were not comparable to residents in our main study area (composed of old houses situated near the proposed cleanup area. **[emphasis added]** Residents from neighboring areas of Granite City were far more comparable to our target group, ...

"Use of a 'control group' is actually an error in the design of studies of the effects of residential lead, unless it can be shown that the control group is like the study group in every respect except soil lead level. Our sample of subjects drawn from a more homogeneous population spread over a distinct gradient of soil lead levels is the only sensible study design under these conditions."

U.S. EPA RESPONSE TO COMMENT H 30:

Residents from the target area are demographically different from residents in outlying parts of Granite City and from residents in similar housing in Madison, in Venice Township, and in unincorporated parts of Madison County. Differences include socioeconomic status (denoted SES) and race or ethnicity, which have been shown in many other studies (e.g. Stark et al. 1982) to be modifying factors in childhood lead exposure. Unfortunately, data provided by IDPH to EPA do not allow evaluation of the characteristics of the target area with those of other parts of the Madison County study area, since there is no geographical location information in the data base that would allow grouping of subjects in other neighborhoods or communities in Madison County as candidate control groups. The data provided by IDPH to EPA does not even include the community within which the subjects are located. The data set includes a crude index of distance from the NL site, but there are parts of Granite City, Venice, or Madison in each ring of distance, with prior observation of these communities suggesting large differences that may affect lead exposure. Therefore, the claim that the other parts of Madison County are appropriate control areas for the target area has not been justified. In view of the potential confounding issues described below, this is a serious deficiency in the design of the study.

U.S. EPA is particularly concerned that little effort appears to have been made by IEHR or by IDPH to identify potential control areas outside of the study area, apart from Pontoon Beach. The characteristics for such an area, which were readily identifiable from many prior studies, would include a gradient of factors with respect to a centrally-located industrial facility such as age of housing, levels and condition of lead-based paint on housing, building condition, race or ethnicity, building condition, income and level of education, but lacking an industrial lead source. A number of small- and medium-sized communities in the Midwest could have been evaluated.

While some care may be needed in matching control communities to target communities, this is a standard method in epidemiologic health studies and the conditions for adequate matching of control groups and exposed groups are readily available in literature (see basic texts, e.g. Rothman, 1986). Even though some environmental lead health studies have not used matching control groups, they sometimes have included a post-study analysis that demonstrates the absence of significant confounding with certain identifiable factors measured in the study. The lack of an external control group is sometimes necessary, but to deliberately fail to include an external control group in a lead health study is to make a virtue of necessity, whereas it must be regarded as a design deficiency with potentially serious consequences in interpreting analyses of the data. IDPH has not yet provided EPA with all of data that are necessary to allow a post-study assessment of the Madison County study to determine whether this design deficiency is merely an annoying complication that can be overcome by suitable re-analyses of the data, or a fatal deficiency that from the very beginning precluded valid inference from the study.

COMMENT H 31 (ML2, pp. 1-2, Sec. 1.3):

"Re-sampling of blood lead, combined with counselling intervention, resulted in a greater drop of blood lead than expected."

U.S. EPA RESPONSE TO COMMENT H 31:

This is an interesting observation, but it has little basis as a generally valid scientific conclusion, since the observed reduction could have occurred for any number of reasons not related to the intervention. Blood lead decreases may have also occurred in children with similar blood lead concentrations in other households, had the investigators chosen to include control groups in the follow-up study. These investigators seem indifferent to the importance of control groups in establishing valid scientific conclusions, as noted in Response ML1. The quantitative effects of counselling and intervention on child blood lead, and the persistence or lack of persistence of such effects over seasons and years are important questions. The expenditure of resources to obtain data that were guaranteed to be inconclusive by the design (or lack of design) of the followup study is most regrettable.

COMMENT H 32 (ML3, p. 2, Sec. 2.3, para. 2): "Ten soil samples were collected from the primary play areas in the yard around each house. No soil samples were taken from within the drip line of the house. A composite soil sample was made from the ten samples. This procedure should have yielded a representative soil sample from the yards and play areas. Since the great majority of the yards were very small, it is highly unlikely that the soil sampling protocol could have yielded unrepresentative soil sample results."

U.S. EPA RESPONSE TO COMMENT H 32:

The absence of drip line samples implies that these measurements are not exactly comparable to those used in calibrating the IEUBK model. Sampling protocols used by EPA and other investigators require that some samples be collected within 0.5 to 1 meter of the housing unit outside wall. The dripline or house perimeter samples usually have higher soil lead concentrations than those taken further out in the yard, since they include some rooftop runoff with airborne particles deposited there, along with some of the flaking and chaking exterior lead-based paint when it is present. Dripline soil samples tend to give better prediction of dust lead levels at the house entry areas and interior, so are useful for understanding lead pathways. Since some children play near the house, soil lead samples may also be predictive of child blood lead (Wesolowski et al., 1983). We would therefore expect that lead concentrations in the Madison County soil samples are: (i) less affected by exterior lead-based paint than perimeter soil samples or composite samples containing perimeter soil than in other studies; (ii) less predictive of interior dust lead than soil samples collected in other studies. U.S. EPA's reanalyses of the data suggest that this may indeed have occurred.

COMMENT H 33 (ML4, Sec. 3.1, p.2):

"Employing a nonlinear age covariate in blood lead regression models could increase slightly the amount of blood lead variance accounted for by age. That would have the effect of reducing slightly the amount of variance in blood lead remaining for other variables, such as soil and dust, to explain."

U.S. EPA RESPONSE TO COMMENT H 33:

The purpose of the analytical modelling should have been directed towards the development of models that could be used to better assess the effects of changes in lead exposure on child blood lead. It has long been known that the child's age can be used as a surrogate for changes in the child's behavior that affect exposure to lead in soil, dust, and paint, and also affects the rate of ingestion of these media (Stark et al., 1982; Bornschein et al., 1985; U.S. EPA, 1986, 1989). The amount of soil and dust ingested during normal hand-to-mouth activity tends to a maximum (relative to the size of the child) between ages 15 months and 3 or 4 years for most U.S. children. For risk assessment purposes, the child's age is far more useful in assessing the consequences of changes in exposure. In our reanalyses of the Madison County lead data, inclusion of child age as a nonlinear modifying factor improved the goodness of fit of the statistical model significantly. The IEUBK model for lead in children uses age as the basis for adjusting blood lead for the growth of the child, and for changes in ingestion rates, in lead absorption, and in biokinetic parameters. In view of the important differences in lead exposure and uptake for children of different ages that account for differences in blood lead at different ages, even as observed in the IEHR/IDPH report, we believe that further evaluation of age-related differences might have been informative.

COMMENT H 34 (ML5, Section 3.2, p. 3, para. 1-3):

"None of our analyses, besides those involving distance from the smelter, depend in any way upon spatial location.

"Soil lead is not uniformly distributed around the closed smelter either. Although soil lead levels decrease with distance from the closed smelter, there are hot spots and irregularities in the soil lead distribution throughout the sampling area. The sampling areas (zones 1--4) were used only to obtain a representative sample of homes and children across the entire range of soil lead levels, regardless of location. Neither distance, nor any other location variable, enters into the main multiple regression/correlation analysis -- the point of which is to use the joint distribution of blood, soil, paint, dust and water lead measures in the homes and yards of study participants, regardless of location, to understand how the variables are associated with one another.

"The spatial distribution of blood lead is of interest because it can sometimes help to locate and explain clusters of high blood lead cases."

U.S. EPA RESPONSE TO COMMENT H 34:

These statements appear to be an attempt to justify the investigators' failure to use the extensive collection of previous studies on the site to assist in the design of the Madison County health study. Earlier studies, such as the 1983 Illinois EPA report, clearly identify the non-uniform distribution of soil lead around the NL site, and the existence of isolated areas of higher soil lead in more remote areas of Madison County. These areas often correspond to identifiable sources of contamination from non-smelter sources, and are believed to vary by community. Examples include use of lead-contaminated wastes for street repair in Venice Township, and use of lead-contaminated waste for yard fill in Eagle Park Acres and elsewhere. Even in areas near the NL site, the distribution of lead in soil was not uniform, as reported by Illinois EPA in 1983, possibly due to differences in patterns of deposition of wind-borne lead particles and of surface water runoff from the site. The investigators appear to have been unaware that lead from different sources may have the potential for different risks to children as a consequence of differences in physical and chemical properties of the lead related to its source. These differences were apparently not considered in their design of the Madison County health study, and we cannot reconstruct this information from the limited data provided to EPA without knowing the location of the sampling sites. The statistical analyses in the IEHR/IDPH report appear to have been carried out as a purely numerical exercise without an understanding of the important physical or chemical properties of environmental media and lead sources that may affect health risk.

COMMENT H 35 (ML6, Sec. 3.2, p. 3, para. 3):

"The spatial distribution of blood lead is of interest because it can sometimes help to locate and explain clusters of high blood lead cases. That is why we depicted the physical location of the subjects in the study area. However, it was shown that distance is associated not only with soil lead and blood lead, but with SES, building condition, behavior, and other factors that influence blood lead. Simultaneous spatial depiction of all of these factors cannot be interpreted."

U.S. EPA RESPONSE TO COMMENT H 35:

U.S. EPA used distance from the NL site in the EPA reanalyses because it was the only location variable in the data set provided to EPA. However, Table 1 in EPA's comments of May 23, 1994, made extensive use of Figure 1 in the IEHR/IDPH report because it was the only data provided then, or subsequently, that elucidated the differences in spatial location of risk factors for elevated blood lead in children. There is obviously some confounding of distance with building condition and with SES, but much of this confounding could have been accounted for if neighborhood-level information on building condition, paint condition, soil lead, and paint lead had been provided along with the blood lead data. Graphical techniques for displaying multi-dimensional data have been available in many statistical packages for at least a decade, but even simple overlay maps would have been better than providing no information at all about the spatial confounding of potential risk factors.

COMMENT H 36 (ML7, Sec. 3.2, page 3, para. 3):

"The problem with the unadjusted bivariate tabulation presented by the reviewer in TABLE 1 of the EPA comments is that it totally ignores confounding by these other factors, which we have shown to be present."

U.S. EPA RESPONSE TO COMMENT H 36:

U.S. EPA 's bivariate tabulations and graphs in the October, 1994 EPA report were presented to help the reader understand the results. Multivariate statistical methods have been used in our detailed reanalyses of these data, with particular attention to assessment of and adjustments for potential confounding by other variables with spatial gradients across the Madison county study area. U.S. EPA will use appropriate graphics and other multivariate methods in our current reassessment of the data.

COMMENT H 37 (ML8, Sec. 3.3, page 3):

"The reviewer took a meaningful linear multiple regression equation, mistakenly attempted to exponentiate the entire equation, and transformed it into a meaningless expression. The reviewer obviously misunderstood both the use of logs of the environmental and blood lead variables, and the meaning of the original regression equation."

U.S. EPA RESPONSE TO COMMENT H 37:

The reviewers admit that there was a serious typographical error in the equation in the report of May 23, 1994; this was corrected in a September 18 draft. We regret any confusion that may have arisen as a result of this. However, the basic point is correct.

The regression equations presented in the IEHR/IDPH report are in general of the form:

$$\log(\text{blood lead}) = a + b \log(\text{soil lead concentration}) + c \log(\text{CXRFIAV}) + \text{other terms}.$$

CXRFIAV is the average product of interior paint condition and interior lead paint loading measured by a portable X-ray fluorescence analyses (XRF), used in the IEHR/IDPH report without separating the effects of paint condition and lead loading. The estimates of the parameters, here denoted a, b, c, etc., were derived from a least-square fit to the data. U.S. EPA trusts that the reviewer will agree that the logarithm or log function has the property that for two positive numbers, say x and y, the logarithm of their product is the sum of their logarithms,

$$\log(x\ y) = \log(x) + \log(y),$$

and that if these are natural or base e logarithms whose antilogarithm is the exponential function (denoted by exp), then

$$\exp(\ (\log(x\ y)\ ) = \exp\ (\ \log(x) + \log(y)\ ) = \exp(\ \log(x))\ \exp(\ \log(y)\ ) = x\ \ y.$$

Also, for any number z, $z \log(x) = \log(\ x^z)$.

Going back to the original equation,

$$\exp(\ \log(\text{blood lead})\ ) = \exp(a + b \log(\text{soil lead concentration}) + c \log(\text{CXRFIAV}) + \text{other terms})$$

$$= \exp(a)\ \exp(b \log(\text{soil lead concentration}))\ \exp(\ c \log(\text{CXRFIAV})\ )\ \exp(\text{other terms})$$

$$= \exp(a)\ (\text{soil lead concentration})^b\ \text{CXRFIAV}^c\ * \exp(\text{other terms})$$

$$= \text{blood lead}.$$

This is actually a prediction equation for the mean of the exponential (antilogarithm) of log(blood lead), that is, the geometric mean blood lead concentration. The problem arises when this equation is used to estimate the effects of near-perfect remediation in any medium, so that by setting soil lead = 0, the predicted blood lead is also 0 even if paint is not removed. We have, however, also used a linear equation in logarithms as well as a log-transformed linear model for all EPA reanalyses in order to compare different specifications of the prediction equations.

COMMENT H 38 (ML9); Sec. 3.4, p. 4, lines 2-8:

"The reviewer incorrectly states that R2 is not a "measure of effect", when the opposite is true.

' ... proportion of variance and correlation measures of various kinds. These are measures of 'effect size,' of the magnitude of the phenomenon being studied.' Cohen & Cohen, in Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences., ... p. 5-7"

U.S. EPA RESPONSE TO COMMENT H 38:

There may be a difference in the use of the term "effect size" in different scientific fields. While the term "effect size" is commonly used for statistical parameters such as standardized regression coefficients or correlation coefficients as used in the behavioral and social sciences, more recent thinking in many areas of human epidemiology discourage the use of these parameters in favor of regression coefficients, mean differences, risk rates (relative risks) or analogous parameters that can be used to assign changes in effect or response (such as differences in blood lead) to changes in a partial or contributing risk factor for or cause of that effect (such as differences in dust lead loading). As Greenland et al. comment, "Ostensibly, standardized coefficients allow the comparison of effects of variables, including those having different scales of measurement., In reality, the usual methods of standardizing coefficients ... distort the assessment of effects precisely because they confound the effect of a risk factor with the standard deviations of the factor and the disease. ... these distortions can arise in epidemiologic applications of standardized coefficients; correlation coefficients, and related measures." (S. Greenland, J.J. Schlesselman, M.H. Criqui, "The fallacy of employing standardized regression coefficients and correlations as measures of effect", American Journal of Epidemiology, Vol. 123 (No. 2), February, 1986, pp. 203-208). They further point out (p. 204) "... that neither standardized coefficients nor correlations should be used to compare the effects of a risk factor in different populations. But standardized coefficients and correlations should also be avoided when comparing the effects of different risk factors whether across or within populations." As to appropriate measures of effect, these authors note (p. 206) that "... standardized coefficients give a distorted measure of biologic effect because they depend not only on the magnitude of the biologic effect, but also on the distribution of the risk factor; when they employ division by the standard deviation of the outcome [e.g., a partial correlation] they also depend on the marginal distribution of the study outcome. In other words, a standardized coefficient confounds the effect of a factor on risk with the background frequencies of both the favor and the outcome. ... another problem with the use of partial correlations as measures of effect: the magnitude of such correlations can be expected to change upon control of additional variables, even if these variables lack one of the two associations necessary to be a confounder ...". If the analyses use multiple risk factors, such as in the blood lead regression models fitted in the IEHR/IDPH report, then these comments on correlations and partial correlations are easily extended to the more general parameters of R2 and partial components of R2.

The interpretation of R2 as "proportion of variance explained" is also criticized (p.208). The primary interpretation of R2 in the IEHR/IDPH report is as the percentage of variance "explained" by the predictors in the regression models for the logarithm of blood lead. The amount of variance in the logarithm of blood lead depends on the range of variation of each of the potential risk factors for lead. The amount of lead in the environment as measured by dust lead loading is the primary predictor, contributing most to the range of variation in blood lead. What is of interest, however, is the actual or estimated blood lead concentration within that range, in reference to external health-related criterion levels such as 10 ug/dl as an index of elevated blood lead. The use of the regression coefficient of blood lead on environmental, behavioral, and demographic risk factors, or the logistic regression coefficient of the risk of elevated blood lead on these factors, is directly relevant to risk assessment and to the determination of appropriate remediation criteria. The correlation coefficient is related to the regression coefficient, but scaling the regression coefficient by the standard deviations of log blood lead and log dust lead (or other risk factor) means that the correlation coefficient by itself cannot be used to estimate the **actual difference in blood lead** that can be expected from a difference in levels of dust lead or any other risk factor. In this study as in most studies in environmental epidemiology, these regression coefficients are the most relevant characteristics of "effect size". As Greenland et al. (1986, p. 208) conclude: "In summary, standardized regression coefficients, correlations, and path coefficients have no meaningful biologic or public health interpretation as measures of effect. We therefore recommend that their use be avoided in epidemiologic analyses." Thus, the reasons why the use of the term of "effect size" in epidemiologic analysis excludes the use of the correlation coefficient as a measure of effect for single risk factors, and the avoidance of the use of multiple correlation coefficients (such as R) for effects of multiple risk factors,.

Perhaps it would be useful to distinguish two uses of statistical parameters. The first is to provide some guidance as to whether a hypothesized effect is "real', i.e., likely to differ from zero effect or no association, in which application the R2 statistic may be useful. The second application is to estimate the likely consequence of differences in levels of a risk factor or lead exposure on the health outcome such as blood lead or the probability of finding an elevated blood lead in a child with a certain level of exposure. R2 is of no use in predicting differences in blood lead associated with differences in exposure, whereas the regression coefficients allow calculation of the expected difference in blood lead or in the risk of an elevated blood lead for specified differences in the predictor variables or risk factors included in the regression model.

COMMENT H 39 (ML10); Sec. 3.4., p. 4, para. 2:

"In our regression analysis of soil lead and blood lead, we avoided including variables that could possibly confound the soil lead/blood lead relationship if including the other variables could over adjust (reduce) the size of the soil lead effect. The argument presented by the reviewer makes the incorrect assumption that including other variables might have increased the soil lead contribution. That is impossible. Every "adjustment"variable included in the regression model ahead of soil lead would necessarily account for some additional portion of the blood variance, thereby further reducing the variance left for soil to account for."

U.S. EPA RESPONSE TO COMMENT H 39:

The inclusion of additional predictor variables in a regression model has at least three purposes. The first reason for including an additional predictor, and by far the most important, is that there may exist other evidence, based on other studies or on theoretical reasoning, that suggests the additional variables have explicit causal or mechanistic roles in the relationship being modeled and therefore should be included. The second purpose is that including the correct predictors may greatly reduce the residual variance and thereby greatly increase the statistical significance of the remaining predictors, even if there is less variance for them to explain, since the purpose of the regression model is to explain components of the health outcome variable. The final reason for including additional predictors is that they may in fact account for apparently confounded relationships among other variables.

Dust lead has been identified as a major contributor to child blood lead in virtually every other statistical analysis of cross-sectional child blood lead studies. Most other investigators would have included dust lead as the primary predictor variable or proxy for environmental lead exposure, which is known to include soil lead as a significant source of dust lead and therefore as an indirect predictor of blood lead.

The next reason for including dust lead is that its inclusion in a regression model greatly reduces the unexplained residual variance of blood lead in the model, which is likely to **increase** the statistical significance of other real predictors of blood lead and thus improve the possibility of identify real risk factors for elevated blood lead. In fact, including dust lead reduced the residual variance of the logarithm of blood lead from about 80 percent of the total variance to about 60 percent of the total variance, a major improvement in the ability of the regression model to identify additional risk factors.

Finally, in spite of the commentor's concerns, and those expressed in the IEHR/IDPH report which were not backed up by quantitative evaluation, soil lead is not profoundly confounded with dust lead. EPA analyses that included both soil lead and dust lead in the regression model, both in fixed and in stepwise regression models, and in a variety of hierarchical regression models, found that soil lead had a smaller and less significant role in blood lead than did dust lead, but that both soil lead and dust lead were significant predictors of blood lead. The advantage of a two-phase model is that it clarifies what are in fact two distinct lead exposure pathways from soil, a **direct** pathway and an **indirect** pathway from soil lead to blood lead through house dust lead. In the Madison County study, the indirect pathway appears to be more significant pathway.

COMMENT H 40 (ML11); Sec. 3.4, para. 3, p. 4:

"Parameter estimates found in the final step in any stepwise multiple regression procedure capitalize on chance, and are not reliable. ... Stepwise procedures are only an aid in early exploration of the data, to be used along with careful consideration of the simple correlation matrix, and to be interpreted in the context of the earlier steps of the procedure, in which other variables enter and leave the equation."

U.S. EPA RESPONSE TO COMMENT H 40:

U.S. EPA's reanalyses of the data found little basis for this comment in the Madison County Lead Study data. Virtually identical regression models were obtained by including dust lead in a stepwise regression model, and excluding distance or inverse distance from the model while including soil lead and other variables that had even marginally significant bivariate correlations with blood lead. A large list of candidate variables was analyzed using a mixture of backward, forward, forward / backward, partially fixed, and partially hierarchical stepwise regression methods. This indicated that the final models reflected a pattern of substantially separable (i.e., not seriously confounded) predictor variables, of which the most important consistently included dust lead, outdoor play hours, building condition, race or ethnicity, age, socioeconomic status (most frequently indicated by parental education or the number of cigarettes smoked), then soil lead (statistically significant), water lead (less significant, but at least marginally significant), and sometimes other SES variables such as renter/owner status. There is a clear pattern of predictiveness of these variables, similar to the pattern found in many other cross-sectional studies, reflecting the consistent working of known environmental, behavioral and demographic factors, not merely chance.

Bivariate correlations do not adequately display the structure of the data. Multivariate methods such as principal components analyses used in EPA reanalyses were far more informative. They showed that the Madison County Lead Study had little potential for confounding except as noted above, that geometric mean soil lead at each distance ring was nearly inversely proportional to distance from the NL site.

COMMENT H 41 (ML12); Sec. 3.4, last para., p. 4:

"The individual parameter estimates in any single step of a multiple regression model do not adequately express the adjusted contributions of the main study factors. In multiple regression, there is no substitute for set-wise hierarchical regression when attempting to adjust for confounding."

U.S. EPA RESPONSE TO COMMENT H 41:

On the contrary, the individual parameter estimates provide the most valid criteria for effect size of the various model components. In the absence of serious confounding effects, the regression coefficients provide an adequate basis for assessing the contribution of different terms. Hierarchical regression modelling is one approach to evaluating the role of soil lead, but a more useful approach is to evaluate the stability of the regression coefficients for soil lead and dust lead when other potentially confounding variables are included in the model.

Hierarchical modeling is meaningful only in a correctly specified model. Blood lead regression models omitting the central role of dust lead must be regarded as misspecified. EPA reanalyses that included dust lead found that soil lead made statistically significant contributions to blood lead indirectly through dust lead, and additionally a small direct contribution. Other model misspecifications in the IEHR/IDPH report, such as functional form of the models, were noted in EPA's May 23 comments.

COMMENT H 42 (ML13); Sec. 3.5., p. 4, last para.:

"Pathway analysis as proposed is a subjective exercise that depends on the assumptions of the analyst. ... we described the importance of paint as a major contributor to dust lead in our study."

"The point of Table 12 is missed entirely by the reviewer of this section, who misinterpreted the parameter estimates for paint, dust, and soil presented in the second model."

U.S. EPA RESPONSE TO COMMENT H 42:

The pathway models discussed by EPA really involve only the simultaneous estimation of models for lead in house dust and in child blood that are analogous to those reported in Tables 10 and 11. In addition to physical evidence on lead pathways as indicated by stable lead isotopes (Rabinowitz et al., 1987; Wesolowski et al., 1983), statistical studies on environmental lead pathways have been prepared for the Boston and Cincinnati Prospective Lead Studies, for studies in western communities such as Telluride and Leadville, CO, Midvale UT, Butte and East Helena MT, Kellogg ID, and for the Baltimore, Boston, and Cincinnati components of the Urban Soil Lead Abatement Demonstration Projects. The pathway models are similar in all studies, with lead in soil, air, and paint as dust lead sources, and dust as the primary contributor to child blood lead through hand-mouth activity. The results of these studies differ only in the estimated magnitude of the environmental and child exposure and uptake pathways, in ways that are sufficiently predictable to be incorporated in the EPA IEUBK Model. These studies all note that exterior paint can contribute lead to soil, and that soil and interior paint can contribute lead to house dust.

As noted in Responses to ML9-12, the regression coefficients from statistical models can provide a valid basis for estimates of the blood lead concentrations and the risk of elevated blood lead attributable to environmental lead exposure to specified levels of lead in residential soil and dust, which neither individual variable nor setwise (R2) correlation coefficients cannot. The issue is not whether the regression parameters in Tables 10-12 in the IEHR/IDPH report should have been reported and interpreted; there was virtually no alternative, since the R2 increments cannot be used for risk estimation purposes, nor for drawing inferences about potential health risks at different levels of environmental lead. The issue is whether the coefficients as reported in these Tables are valid. EPA reanalyses suggest that, for all of the inadequacies described in the EPA comments of May 23, 1994, the results in Tables 10 and 12 provide a far more accurate description of childhood lead exposure than does the incomplete hierarchical analysis in Table 11.

Comment H 43 (ML14); Sec. 3.5., p. 4, last para., and p. 5: "The point of Table 12 is missed entirely by the reviewer of this section, who misinterpreted the parameter estimates for paint, dust, and soil presented in the second model. The correct interpretation of this analysis rests on the increment in R2 when soil is added to the model. ... Paint and building condition account for 26% of the dust lead variance. The addition of soil lead measures account for another 6% of dust lead variance, less than 1/4 of the value of paint. Interpreting only the parameter estimates for the variables in Model 2 ignores the central meaning of the hierarchical model."

U.S. EPA RESPONSE TO COMMENT H 43:

Paint and building condition are two separate variables; therefore, to state that "soil lead accounts for less than 1/4 the value of paint for dust lead variance" is incorrect. The percent of dust lead variance accounted for by building condition must be separated from 26% to effect a direct comparison of soil lead versus paint contribution to dust lead variance.

The parameter estimates in Table 12, Model 2, would have been the same for this set of predictor variables, whatever hierarchical, stepwise, or forced entry regression model had been used, so that "misinterpretation" of the estimates is not an issue. Other hierarchical approaches, such as using lead paint and soil lead as predictors and then forcing in building condition, would have tested the hypothesis that lead sources must first be included in a model. Our conclusions from the final statistical model from the Madison County Lead Study, although inferential rather than observational, are entirely consistent with the findings of more direct physical methods used in lead isotope and mass balance studies carried out in other communities: lead in soil and lead in deteriorating interior paint both contribute to lead in household dust. In particular, since soil lead concentrations in the rings nearest the NL site are much higher than more distant parts of Madison County, the soil lead contribution to house dust is estimated to be much greater than the interior paint contribution at most residences near the NL site, with EPA reanalyses using several different approaches supporting these conclusions. The EPA reanalyses further suggest that there is sufficiently little confounding of the factors in this model, so that the regression coefficients should have little sensitivity to estimated coefficients for other predictors.

One possibly serious bias is that the role of lead paint in the dust lead measurements may be inflated by inclusion of lead paint chips in the dust samples. In most dust sampling and reporting protocols used in other studies, dust samples have been sieved so as to remove larger debris from the sample, since large particles are much less likely to adhere to a young child's hands and fingers than small particles. While the samples in the Madison County were sieved, the reported results represent a mathematical composite of lead concentrations in large and small particles. This does not mean that the reported dust lead concentrations cannot be used for some applications, as in the empirical statistical relationships between dust lead and blood lead noted above, but rather, that the results may not be directly comparable to those from other cross-sectional studies. It is more likely that the reported concentrations in samples containing large lead paint chips are larger than would have been obtained if only the lead concentrations in the finer dust particles had been reported.

The inclusion of building condition as a covariate needs some discussion. In the first place, about 30 percent of the values of building condition were not recorded. When not included in the analysis, this high fraction of missing data seriously weakens the results, especially as there has been no demonstration that building condition data are missing in ways that correlated with other variables in the data set (i.e., data are not missing at random). In some applications, including Table 12, it appears that missing values of building condition were imputed by the mean value, which may also bias the results. In fact, the sample size in Table 12 (N = 433) is much larger than the number of households with preschool children, and suggests that the analyses of the environmental data were done using the same data set as contained individual child data, implicitly weighing each household in the analysis by the number of preschool children who reside there. This may be a defensible judgement, but should be noted and justified if possible.

As noted by the commentor, building condition and paint condition are somewhat correlated. Including both log of the average product of interior paint and of exterior paint with paint condition, as well as building or residence condition, tends to "triple count" three correlated modifying variables in the regression model.

COMMENT H 44 (ML15); Sec. 3.6, para 1., p. 5:

"... adding behavioral or other variables to a hierarchical regression model can only reduce the variance accounted for by soil."

U.S. EPA RESPONSE TO COMMENT H 44:

Inclusion of appropriate major covariates such as household dust lead may actually increase the size of an estimated lead effect as well as the statistical significance of the effect by greatly reducing the amount of residual variance and removing the confounding with the previously omitted covariate.

COMMENT H 45 (ML16); Sec. 3.6, para 1, p. 5:

"Behavioral variables can over adjust the effects of the main environmental variables, including soil, because behaviors are the pathways for environmental lead to reach the blood."

U.S. EPA RESPONSE TO COMMENT H 45:

Behaviors can greatly modify the effect on blood lead of lead concentrations observed in various environmental media because the amount of the medium (soil, dust, water, paint, food etc.) ingested by the child may depend on those behaviors. However, it is important to distinguish between the role of the behavioral variables as modifiers of lead intake, and the more essential role of environmental lead concentrations as the primary factor in lead intake. All of the lead in the child's body is derived from some environmental source through current or previous intake from an environmental medium, possibly even extending back through the mother's exposure to lead. In a nutshell, if there were no lead in the environment, there would be no lead in the child. Behavior can affect the amount of lead intake directly, and can also serve as a confounding variable for some other sociodemographic factor or environmental variable that is a surrogate for lead intake from other sources. In any event, there is only modest confounding between behavioral variables and lead in soil or dust.

COMMENT H 46 (ML17); Sec. 3.6, para. 2, p. 5:

"We have presented and discussed numerous bivariate relationships ... in order to show the intercorrelation of these variables. ... we did not feel that it was possible to interpret multivariate analyses if we included all of these variables at once."

U.S. EPA RESPONSE TO COMMENT H 46:

U.S. EPA agrees, but believes that the discussion in the IEHR/IDPH was incomplete because it omitted a large number of significant relationships (or in some cases, lack of relationship) that merited comment as much as those bivariate relationships that were selected. A more complete reporting of results would have greatly aided some readers, and would have clarified many of the issues concerning variable selection and confounding.

COMMENT H 47 (ML18); Sec. 3.7, p. 5:

"The comments in this section are correct, but this is exactly the opposite of the point of the preceding reviewer's comment (3.6). Our analysis avoided the problems of multicollinearity by not including variables that could be proxies for one another. None of the variables included in the regression models are linked in this way."

U.S. EPA RESPONSE TO COMMENT H 47:

The comments in the May 23, 1994 EPA report included some speculations on the possible effects of collinearity, given the lack of quantitative information in the IEHR/IDPH report that allowed assessment of this issue. The IEHR/IDPH report and the response by the commentor attempt to justify exclusion of statistically related (collinear) exposure variables from statistical analyses such as multiple regression. This is not, properly, an example of confounding, since soil lead, paint, dust lead concentration, and dust lead loading are simply steps on a causal pathway from source terms (soil, paint) through an intermediate medium (dust) to the child. The existence of this pathway as an important pathway, usually the most important exposure pathway for most children, has been established using a variety of scientific approaches (see discussion below in part B), and was not disputed by the scientific expert group consensus of February 6, 1995. Use of different components of an exposure pathway is discussed in standard epidemiology texts, such as Modern Epidemiology by K. Rothman (1986). However, neither the IEHR/IDPH report nor Dr. LeVois's response have actually attempted to determine the extent of the "confounding" they claim exists in the Madison County Study.

"Confounding" is a term that is widely used in epidemiology and other observational sciences. Confounding occurs when some third variable or factor is related both to the outcome or response being studied -- in this case, childhood blood lead -- and to the nominal cause of the outcome, such as lead in dust or soil. As noted in our "Preliminary Assessment" of October 1994, several factors appear to match the decline in mean blood lead with increasing distance from the NL site, including decreasing soil lead and dust lead, decreasing housing age and deterioration, increasing parental education and income. These are potential confounding factors.

Confounding is a **potential** problem in this study. Is the problem real? U.S. EPA has evaluated quantitatively the amount of confounding, to the extent that it can be defined internally from the data in the study, in a draft report in preparation. Confounding has both a conceptual aspect and a technical aspect. Conceptually, confounding can occur as a result of failure to design an appropriately representative sample. Some of the confounding in the Madison County Lead Study could have been avoided by better design of the study. When the confounding is not avoided by design, then some statistical methods may allow quantitative identification of potentially confounded variables. In linear statistical models, confounding can be identified by statistical methods that identify a technical condition known as collinearity. The collinearity diagnostics among the 30 most plausible predictors have shown that collinearity as a serious problem only occurs under three conditions:

(i) when the logarithms of dust lead loading, dust lead concentration, and total dust loading are all used in a regression model, there is a perfect collinearity as shown above;

(ii) the logarithm of the shifted variable CXRFIAV, the mean of the product of paint condition and XRF lead loading on interior surfaces, is highly correlated with the logarithm of the mean XRF, and using both in a regression model causes a loss of information efficiency;

(iii) the logarithm of soil lead is highly correlated with the logarithm of distance (geometric mean soil lead in each ring is nearly inversely proportional to distance), and the use of both log of soil lead and log of distance in the same equation should be avoided. If these combinations are avoided, then there are no severe collinearities and the effects of most other predictors or covariates can be estimated separately in joint regressions with only a modest degree of variance inflation.

Household covariates are responsible for part of the variation in blood lead, and including demographic covariates such as race or ethnicity, parental education or home ownership in a model will generally reduce the unexplained variance in blood lead. These variables are not so highly correlated with soil lead, however, and are therefore weak confounders of the relationship.

In a non-technical sense, there is only a slight to moderate amount of confounding between soil lead and blood lead. For example, there is only relatively modest confounding with dust lead. Within each distance or ring, there is some variation in soil lead concentrations. However, for any soil lead concentration, there are housing units with both lower and higher dust lead concentrations and children with both higher and lower blood leads. Therefore, the interfering effects of dust lead differences (using dust lead as the closest predictor of blood lead on the pathway, and as an indirect exposure pathway from soil lead to blood lead) can be minimized. Likewise, sociodemographic factors or building condition can be related to both blood lead and soil lead, since a range of sociodemographic variables at almost all levels of soil lead or dust lead..

In summary, extensive diagnostic analyses of a variety of statistical models find that confounding is a worrisome but not insurmountable problem in estimating separate effects of lead in soil, dust, and paint. Careful analyses of the Madison County data set can adequately characterize the typical contributions of lead in paint to soil, the contributions of lead in soil and paint to lead in household dust, and to a substantial extent can separate partial contributions of soil lead and dust lead to blood lead.

COMMENT H 48 (ML19) Sec. 3.7, p. 5:

"... measurement error ... does not change the relationship of the variables as long as the errors in measurement are not systematic."

U.S. EPA RESPONSE TO COMMENT H 48:

It has long been known that in multiple linear regression models, where the covariates as well as the predictor of interest are correlated and measured with error, measurement error can either inflate or attenuate the apparent regression coefficient and can even change the sign of the relationship (e.g. L. Kupper, "Effects of the use of unreliable surrogate variables on the validity of epidemiologic research studies," American Journal of Epidemiology, Vol. 120 (1984), pp. 643-648).

COMMENT H 49 (ML20); Sec. 4.1, p. 6:

"We used 500 ug/g soil lead, and 10 ug/dl blood lead to conduct some two-group analyses ..."

U.S. EPA RESPONSE TO COMMENT H 49:

While useful for providing tabular results, categorizing continuous data generally results in a loss of information.

COMMENT H 50 (ML21); Sec. 5.1, p. 6:

"These slightly elevated [blood lead] levels were largely in children from relatively poor, unemployed families, living in rundown houses. Our interpretation is consistent with recommendations made by CDC ..."

U.S. EPA RESPONSE TO COMMENT H 50:

U.S. EPA agrees that these are potentially important factors that can modify the risk of elevated blood lead from lead exposure. However, without current or historic exposure to some source(s) of environmental lead, there would be no lead intake that could be modified by these factors. Elevated blood lead concentrations show a clear gradient with respect to source concentrations in soil or paint as transferred to the child mainly through household dust. Elimination of significant environmental lead sources inside and outside the child's residence can be expected to substantially reduce current environmental lead exposure, with an eventual reduction in blood lead as the child's body eliminates stored body burdens of lead.

Comment H 51 (ML22, Sec. 5.2, p. 6):

"... age was intentionally <u>not</u> used in the regression analysis ... because age is a proxy for exposure -- through mouthing behavior ..."

U.S. EPA Response to Comment H 51:

A large number of child behaviors are age-dependent and may affect exposure or uptake of lead. These may include the amount of time spent at home, the number of hours playing outdoors or on the floor, propensity for mouthing non-food objects, etc. We agree that it may be possible to include enough behavioral variables to adequately characterize the age-dependence of child blood lead levels. Some of our own experiences suggest a simple but adequate parameterization can be obtained by trichotomizing child age into intervals (< 1 year; 1 to 3 years; 4 years or older). Age-dependent modifying factors for lead exposure generally reduce the residual variability of blood lead as well as reducing the confounding of age with other factors, but any of several adequate modeling approaches may be used.

Comment H 52 (ML23, Sec. 5.3, p. 7): "The correlation of distance and blood lead was reported. There were other important correlations with distance that were also reported ... A much better indication of the association of blood lead and soil lead may be obtained by direct analysis of these two factors than can be gained by gerrymandering neighborhood subunits of the sample and speculation about clusters."

U.S. EPA RESPONSE TO COMMENT H 52:
The neighborhood subunits were not "gerrymandered", but were based in large part on prior knowledge about environmental lead sources in different Madison County communities, and secondarily on neighborhood or political subdivisions that were known to be important predictors of demographic differences of lead exposure. Some of the factors include:

(i) soil lead measurements and isopleths reported by Illinois EPA in 1983 and U.S. EPA in 1990, identifying a clear "downwind" pattern for concentration of elevated soil lead concentrations in areas near the NL site, reaching further towards the north and east of the closed smelter;

(ii) locations in the Venice Township and Eagle Park Acres communities that were known sites of lead contamination, where waste materials from the pile on the NL site and battery casing chips were used for purposes such as street or driveway repair and for yard fill;

(iii) demographic differences among communities such as Granite City, Madison, and Venice Township with respect to income, ethnicity, and renter/owner status, often clearly visible and associated with discrete neighborhoods separated by physical boundaries such as major streets or railroad tracks. The lack of use of important information in designing the Madison County Lead study certainly complicates analyses of the data, especially as IDPH has not yet presented EPA with any location information that would allow testing hypotheses about spatial clusters of cases of elevated blood lead in these communities.

U.S. EPA also used soil lead concentration in most of the EPA reanalyses, rather than distance from the NL site. The reason for this is that one of the most significant sources of potential confounding is evident from Table 10 of the IEHR/IDPH report. When distance is used as a covariate, it is essentially a substitute for soil lead, to a greater extent than other potentially important predictors of blood lead. Of all the variables in the study, none is seriously confounded with distance from the NL site except for soil lead concentration. The range of soil lead concentrations in any ring is relatively small, so that soil lead and distance are relatively highly correlated with each other. The average soil lead in each ring is very nearly inversely proportional to the distance of the ring from the smelter. In this regard, the soil lead distribution around the NL site looks very similar to every other lead smelter community we have studied.

However, U.S. EPA has analyzed the relationship between soil lead and the only other plausible source of elevated lead concentration in residential yard soils, deteriorating exterior lead-based paint. U.S. EPA found that there was a consistent contribution of exterior lead-based to soil that was approximately the same at any distance from the NL site. Similar results were obtained by several different analytical methods (linear and non-linear regression, structural equations modelling). The condition of the building was used as a covariate in many of the analyses, as were other sociodemographic variables, and their interactions were tested. When the estimated contribution of exterior-lead-based paint and building condition were subtracted from the observed soil lead concentration, there remained a large positive fraction of soil lead at most residences that was not explained by lead paint or by building condition. This component could be reasonably attributed to historical deposition of airborne particles emitted by the smelter and dust particles blown off the site. Neither the building condition nor the background term were ever statistically significant. The best-fitting model (smallest residual variance) was a very simple linear model, fitted in log form:

$$\text{Soil lead concentration} = (1333 / \text{distance}) + 7.79\ \text{CXRFOAV},$$

where distance = ring number 1 through 10, and where CXRFOAV is the average of the exterior XRF lead paint loading times the exterior paint condition. Since CXRFOAV never exceeded 62.3, and was usually much smaller, the lead paint contribution was always less than 500, usually much less, the remaining term which depended on distance was dominant near the NL site. There was little evidence of confounding between distance and exterior paint. We conclude that most of the lead in soil near the NL site must be attributed to some processes by which lead is transported from the smelter to the surrounding yards. This implies that much of lead in soil near the NL site will have properties similar to those of other former smelter communities we have studied: high bioavailability and ready transport from surface soil into the household dust.

There are some relatively high soil lead concentrations far away from the site, attributable to lead paint or to other sources such as use of waste materials for fill or for street repair. These cannot be confirmed since IDPH has not provided us with any information about the location of these residences. It is likely that these few exceptional cases (4 out of 351 units) are found in places such as Venice Township or Eagle Park Acres.

COMMENT H 53 (ML24); Sec. 5.5, p. 7:

"... it would have been a mistake to include dust lead in the analysis of soil and paint lead (as recommended by the reviewer). Since dust lead is almost entirely dependent on the lead in paint and soil, multicolinearity in the regression of all three environmental variables against blood lead could only produce a meaningless regression model."

U.S. EPA RESPONSE TO COMMENT H 53:

EPA reanalyses demonstrate that meaningful statistical models can be produced using the set of environmental lead variables, which are not so highly collinear as to preclude meaningful analyses. The correlation coefficients among the regression coefficients are not large enough to suggest serious inflation of parameter standard error estimates. Furthermore, even these collinearities can be accounted for by models of environmental lead pathways.

COMMENT H 54 (ML25); Sec. 5.8, p. 8:

"The argument presented by the reviewer supports our decision not to include education, income, or similar SES and behavioral factors in the main hierarchical regression model. It is not clear whether including these factors would correct for, confound, or over-adjust the effects of the environmental measures."

U.S. EPA RESPONSE TO COMMENT H 54:

EPA reanalyses demonstrate that these factors include some useful and predictive covariates that have relatively little potential for confounding the effects of exposure to lead in dust, soil, or water. The decision to unnecessarily exclude these covariates from the hierarchical regression analysis in Table 11 of the IEHR/IDPH report contributes substantially to the low predictiveness of the two models in Table 11; omission of dust lead is the most serious deficiency in the hierarchical analysis, however.

RESPONSES TO COMMENTS

Memo from Renate Kimbrough to Edward Fitzhenry, January 11, 1995

COMMENT H 55 (RK1), p. 1, 14-17 lines from bottom of p.:

"... the blood lead levels of the participating children were quite similar to blood lead levels found in other older urban areas in the United States with housing stock dating back to the first half of this century and with similar incomes ..."

U.S. EPA RESPONSE TO COMMENT H 55:

See response to comment TRC-OBJ1. There is a **localized** soil lead exposure problem, associated with historical emissions from the NL site, with an incidence of about 25 percent elevated blood leads in preschool children. The more distant parts of Madison County, with an incidence of elevated blood lead of about 10 percent, may be more typical of older urban areas. However, isolated locations exist elsewhere in Madison County where there is soil lead contamination from battery chips and other waste materials specific to this site. The comparison of the entire Madison County study area to a national average (which is still higher than is desirable from a health perspective) is an attempt to dilute a local and site-specific problem by averaging the area with an excessive number of lead-burdened children with other areas that have much lower lead exposures.

COMMENT H 56 (RK2), p.2, lines 10-18:

"Unless children eat paint chips, ingestion of lead occurs in children under 6 years of age because of hand to mouth activities primarily through lead containing house dust [**sic**]. House dust is composed of dust from paint and ... dirt brought in from outside, particularly if feet are not wiped. All of these factors must be evaluated together to determine the proportional contribution from all sources."

U.S. EPA RESPONSE TO COMMENT H 56:

U.S. EPA concurs with this comment, as has been noted in most EPA studies on childhood lead exposure. U.S. EPA's concern is that the IEHR/IDPH report has not used this correct statement about childhood lead exposure as a key element in their analyses of the data. This statement identifies childhood lead exposure from soil and from paint as primarily an **indirect** process which occurs in two stages:

(i) transfer of lead from the source medium (soil or paint, primarily) into household dust, which is the medium through which most of the exposure occurs;

(ii) ingestion of household dust by the child. The hierarchical regression models used in the IEHR/IDPH report ignore this well-known fact about childhood lead exposure pathways. EPA has reanalyzed data from the Madison County study using a variety of different analytical approaches, including appropriately structured hierarchical models that include both direct and indirect exposure pathways for lead from soil and from paint.

COMMENT H 57 (RK3) p. 2, 15-19 lines from bottom:

"... distance from the smelter is indicative of improved housing which negates the idea that the smelter was necessarily responsible for the larger number of children with elevated blood lead levels closer to the smelter. ... Dr. Marcus chooses to ignore this observation."

U.S EPA RESPONSE TO COMMENT H 57:

EPA presented a number of graphs that clearly demonstrated our awareness of the possible confounding with distance of both soil lead and sociodemographic factors affecting lead exposure. EPA reanalyses have shown that confounding of these effects is only a modest problem in interpreting the Madison County data, and that appropriate multivariate statistical analyses allow identification of the separate effects of lead in soil and paint on blood lead through household dust. While this problem could have been reduced had the IEHR/IDPH study been better designed, these investigators have not evaluated whether this hypothetical problem actually existed, nor have they investigated methods for dealing with this problem.

COMMENT H 58 (RK4) p. 2, 3-14 lines from bottom:

" The statement ... that loadings of deteriorating lead paint inside and outside the house show little or no relationship to distance from the smelter, is wrong. ... deteriorating house paint in houses built before 1978 is now the primary cause of lead poisoning in children under six years of age ... suggests the author is unfamiliar with lead exposure in small children and the large body of literature available on this subject."

U.S. EPA RESPONSE TO COMMENT H 58:

This comment appears to confuse a general statement about lead exposure in the entire U.S., such as that in the 1991 CDC report, with comments that are directly relevant to the NL site and based on detailed analyses and evaluation of data from that site. EPA's comments were related to a specific set of data for a specific location, those parts of Madison County where the proposed remediation actions are targeted. The conditions elsewhere in the U.S. are of great interest to us, but are absolutely irrelevant to remedial actions at this site. EPA analyses of these data by a variety of techniques clearly demonstrates that the increased incidence of elevated blood lead near the NL site is directly related to the higher incidence of elevated dust lead concentrations and dust lead loadings near the NL site, that dust lead depends on both soil lead and on lead paint, and that the major source of lead in dust near the NL site is lead in soil. In fact, the analyses in the IEHR/IDPH report point to exactly the same conclusions, yet these important conclusions seem to be ignored. The relative contributions of lead in soil and lead in paint at this site clearly show that higher concentrations of lead in soil near the site are associated with the increased incidence of children with elevated blood lead near the site, and constitute a serious risk factor for lead exposure in the future. Lead paint certainly contributes to childhood lead exposure, but the contribution of lead paint to blood lead appears roughly similar across the Madison County study area when other factors, such as building condition, socioeconomic status and race/ethnicity are taken into account. Similar adjustments do not eliminate the role of elevated soil lead as a primary source of lead in house dust near the NL site, therefore soil lead is the primary risk factor in the remediation area.

The EPA scientists who have reviewed the IEHR/IDPH are aware of the importance of investigations that are specific to the conditions at each site, since the EPA scientists have had the advantage of having carried out investigations at many different sites, and are aware of the many ways in which a specific site such as the NL site in Madison County may be similar to other sites. The EPA comments of May 23, 1994, cite a number of specific instances in which the IEHR/IDPH report failed to note many significant and highly relevant publications on lead exposure, lead pathways, and the analysis of environmental lead data at other sites.

COMMENT H 59 (RK5); p. 3, para. 3 and para. 5:

"Dr. Marcus notes that our study participants were all volunteers. He does not state why this concerns him. All such studies use volunteers ... We achieved the highest participation rate in the group closest to the smelter ... the participation rate was not as high in the most distant recruitment area. It is unclear why this is alleged to be a drawback. ..."

U.S. EPA RESPONSE TO COMMENT H 59:

It is possible that the households closest to the NL site may have been far more aware of potential lead hazards associated with the site than households farther away from the site. As noted by the investigators, greater awareness of lead hazards, whether achieved by counselling and education or simply by observing the waste pile across 16th Street, may have caused more protective behavior by child caregivers in these households. The higher participation rates in Areas 2 and 3 than in Area 4 are consistent with this hypothesis. Conversely, households with lower incomes and larger numbers of children and possibly facing higher social stress, such as were found near the site, may account for a slightly reduced participation rate in the parts of Madison County closest to the site. While it is hard to avoid using volunteers in such a study, some thought must be given to the effects of possible biasing factors such as those mentioned here, and to actions that might have been taken to avoid these potential biases.

COMMENT H 60 (RK6); pp. 3-4:

"... the percent of blood lead variance accounted for (R2) is influenced in part by the units of measurement of the different variables."

U.S. EPA RESPONSE TO COMMENT H 60:

Not true. Any elementary statistics text will note that simple correlation coefficient is dimensionless itself, and that it does not depend on the units of measurement of the variables. By an extension of that analysis, neither does the multiple correlation coefficient (R).

COMMENT H 61 (RK7); p. 4, para. 1:

"It is incorrect and misleading to state that ... multiple regression analysis of the blood lead variance accounted for by the different variables) is not a useful way to interpret our data. ... The proportion of blood lead variance accounted for by the different variables can be partitioned through hierarchical modelling, so that confounding effects of some of the variables can be controlled. ..."

U.S. EPA RESPONSE TO COMMENT H 61:

Hierarchical modelling can be informative when it is appropriately used. By ignoring lead in house dust, the single most predictive variable in the data set that by itself can explain nearly half of the explainable variance in the logarithm of blood lead, the hierarchical models presented in the IEHR/IDPH report are so seriously flawed. EPA reanalyses show some more appropriate applications of hierarchical modelling.

COMMENT H 62 (RK8); p. 4, para. 3:

"... in a follow-up study of children with elevated blood lead levels ... the blood lead levels of these children dropped below 10 ug/dl ... the remarkable response of the blood lead levels was accomplished through counselling .... No such drop in blood lead levels was accomplished in studies where the EPA removed lead contaminated soil ... "

U.S EPA RESPONSE TO COMMENT H 62:

This is a very interesting observation, and contributes to our understanding that counselling may be a useful temporary action in reducing lead exposure. The hypothesis that educational intervention produces short-term decreases in blood lead for children who reside in the household is plausible, but the followup study does not allow the hypothesis to be tested, nor the size of the reduction to be estimated, in the absence of any control group. The investigators have again overlooked the importance of valid epidemiologic design of a study.

An assessment of the effect of remediation may be made in at least two different ways. The approach that most closely matches the USLADP is to assume that changes in environmental lead exposure are followed in children who had been previously exposed to higher concentrations. The simulations cited in the Guidance Manual show that it takes about two years to achieve blood lead concentrations similar to those achieved in children two years older who had grown up in the cleaner post-remediation environment. The decrease in blood lead in the second post-remediation year and subsequent years occurs because the internal body burden of lead stored in the skeleton is gradually eliminated, and because house dust is not recontaminated when a primary source of lead in soil is eliminated. This appears to have occurred in the Boston component of the study (Aschengrau et al., 1994), and in the major CERCLA remediation project near Kellogg, Idaho (Von Lindern et al.,1994), but not in the other USLADP projects which did not achieve effective control of contamination from other sources. A better indicator of remediation effectiveness is the blood lead concentration of children who are born in or move into remediated housing while very young.

RESPONSE TO COMMENTS

Section 2: Comments from Morgan, Lewis & Bockius

General Conclusions, page 2:

The commentors have raised a number of issues in the general conclusions section preceding their critique. While these comments will be discussed in more detail, a summary of the majors points is presented here.

COMMENT H 63:

"the Study [the IDPH Blood Lead Study Report] does not demonstrate that the NL/Taracorp site contributes today to elevated blood lead levels or soil lead levels in the subjects tested, because the levels are no higher than would be expected for a comparable, comparison urban neighborhood"

U.S. EPA RESPONSE TO COMMENT H 63:

EPA does not consider the NL/Taracorp NPL site to be a "typical" urban area with respect to lead exposure. Rather than having a multitude of minor diffuse sources of environmental lead contamination, the area is located next to a closed lead smelter, which constituted the predominant source of lead contamination in the community as reflected in the highly elevated soil lead levels near the smelter site. The incidence of elevated blood lead concentrations in children under the age of six living within about a quarter mile of the NL site is about 25 percent compared with an incidence rate of about 10 percent in the more distant locations of the study area and 16 percent in smaller urban areas in the NHANES III study. The comparison of the entire Madison County study area to a national average (which is still higher than is desirable from a health perspective) is an attempt to dilute a local and site-specific problem by averaging the area with an excessive number of lead-burdened children with other areas that have much lower lead exposures. Additionally, the 16% is not to be considered acceptable from a health standpoint.

COMMENT H 64:

"Good science dictates that the agency first identify a reasonable 'control' or background level in order to understand whether there are in fact 'elevated' levels detected by the surveys."

U.S. EPA RESPONSE TO COMMENT H 64:

U.S. EPA agrees that the blood lead study, performed by the Illinois Department of Public Health (IDPH) under contract to ATSDR, should have included a <u>separate</u> control group. However, the IDPH report refers to an internal control group within the study boundaries, and indeed, both the incidence of elevated blood lead concentrations and soil lead levels diminish with distance from the NL smelter site.

The blood lead levels reported in the IDPH study appear to include the internal "control" population as well as the target area in the community average.

COMMENT H 65:

"EPA has not demonstrated that a reduction of the soil lead in this area to 500 ppm would result in a significant reduction of childhood blood leads."

U.S. EPA RESPONSE TO COMMENT H 65:

While CERCLA regulations do not require that EPA demonstrate that any remedial activity will produce a specific reduction in blood lead levels, USEPA does believe that a reduction in lead in soil will reduce the risk of elevated blood lead levels in children typically within a mile to the smelter. There wouldn't be any lead in the child's blood without lead in some environmental medium encountered by the child. Any evaluation of the predicted reduction in children's blood lead levels must be done on a house-by-house basis, using all available data for that exposure unit. To date, such an analysis is constrained by the manner in which the house dust levels were reported in the data set provided to EPA for their reevaluation of the soil lead cleanup level.

EPA believes that the reduction of the soil lead concentration in the area to 500 ppm is appropriate and consistent with removal actions at other sites with contamination from lead smelting operations. Greater reductions in blood lead levels were observed in children with high lead body burdens in the Boston area with soil abatement than with other remedial actions; significant reductions in blood lead levels in children have been seen in Kellogg, Idaho, where nearly 85-90% of the residential properties are scheduled to be remediated to background. While soil remediation has not been effective in some urban remediation studies, where it is possible to prevent recontamination due to removal of a single predominant source of contamination or by interdiction of the child exposure pathway, soil remediation has been effective.

COMMENT H 66:

"the EPA's course is contrary to the conclusions of the Study, which states that '[e]liminating a variable such as soil that accounted for only 3% of the variance [in blood leads] may result in a minimal change in measured blood lead levels without any clinical significance.'"

U.S. EPA RESPONSE TO COMMENT H 66:

The commentors have cited a conclusion of the IDPH study which states that elimination of the soil variable which accounted for only 3% of the variance is likely to result in only minimal changes in measured blood lead levels. The commentors, as well as the authors of "the Study", have failed to realize that soil presents an indirect exposure pathway to the child by way of ingestion of indoor dust, in addition to the direct exposure pathway of ingestion of soil. The authors only considered the latter pathway in their analysis.

Following are more specific health comments and responses:

COMMENT H 67; Specific Comment #1, page 3:

(a) "There appears to be some confusion over the EPA's goal in setting a 500 ppm soil remediation level at this site. ...is EPA simply justifying the clean up because these levels are elevated over the EPA's 'ideal,' regardless of source?"

(b) "The EPA might make a policy determination to clean up soils to 500 ppm, but ... they should be required to prove the source before ordering private parties to fund the clean up. For example, the Study found that for houses with soil leads above 500 ppm the geometric mean outdoor paint lead level was 8.6, but for houses with soil leads less than 500 the mean paint lead was 3.0. This suggests that outdoor lead paint contributes at least in part to elevated soil readings."

U.S. EPA RESPONSE TO COMMENT H 67:

(a) Under CERCLA, it is EPA's charge to protect all generations of children from the adverse health effects of environmental pollutants associated with activities at hazardous waste sites. Region 5 is not aware of any EPA stated "ideal" to have all soil lead below 500 ppm, and cleanup levels ranging from 150 ppm to over a thousand ppm lead in residential soil have been set for lead contaminated sites across the country based on site-specific risk evaluations.

(b) In the reanalysis of risk at the NL/Taracorp site, EPA used the IEUBK Model for Lead in Children to specifically evaluate the contribution of lead in soil by both the direct pathway of exposure and indirect contribution of soil to indoor dust to the child's blood lead concentration. We have evaluated the role of location (as measured by distance from the NL site) as a potential confounding factor. At any given location (ring or group of adjacent rings surrounding the site), there are some houses with higher levels and some with lower levels of almost any other measured variable in the study. Of all the measured variables in the study, none is seriously confounded with distance from the NL site except for soil lead concentration. The range of soil lead concentrations in any ring is relatively small, so that soil lead and distance are relatively highly correlated with each other. The average soil lead in each ring is very nearly inversely proportional to the distance of the ring from the smelter. In this regard, the soil lead distribution around the NL site looks very similar to every other lead smelter community we have studied.

EPA has analyzed the relationship between soil lead and the only other plausible source of elevated lead concentrations in residential yard soils, deteriorating exterior lead-based paint. We found that there was a consistent contribution of exterior lead-based paint to soil that was approximately the same at any distance from the NL site. Similar results were obtained by several different analytical methods (linear and non-linear regression, structural equations modeling). The condition of the building was used as a covariate in many of the analyses, as were other sociodemographic variables, and their interactions were tested. When the estimated contribution of lead-based paint and building condition were subtracted from the observed soil lead concentration, there remained a large positive fraction of soil lead at most residences that was not explained by lead paint or building condition. This component could be reasonably attributed to historical deposition of airborne particles emitted by the smelter and dust particles blown off the site. Neither the building condition nor the background term were ever statistically significant. The best-fitting model (smallest residual variance) was a very simple linear model, fitted in log form:

Soil lead concentration = (1333 / distance) + 7.79 CXRFOAV,

where distance = ring number 1 through 10, and where CXRFOAV is the average of the exterior XRF lead paint loading times the exterior paint condition. Since CXRFOAV never exceeded 62.3, and was usually much smaller, the lead paint contribution was always less than 500, usually much less, the remaining term which depended on distance was dominant near the NL site. There was little evidence of confounding between distance and exterior paint. We conclude that most of the lead in soil near the NL site must be attributed to some processes by which lead is transported from the smelter to the surrounding yards. This implies that much of lead in soil near the NL site will have properties similar to those of other former smelter communities we have studied: high bioavailability and ready transport from surface soil into the household dust.

COMMENT H 68; Specific Comment # 2:

(a) 'The Study indicates that it was unable to find an appropriate 'control' population similar to the Study population in all respects except for the presence of the site. It seems as if a comparable urban area should exist from which actual samples could be taken, perhaps in a nearby city."

(b) In the absence of true background testing, the EPA has not proved that lead levels in this neighborhood are elevated over background."

(c) "The blood lead levels were in keeping with national averages for urban children."

(d) "..the EPA unrealistically compares the data from the Study to the EPA's ideal situation - i.e., 95% of children under 6 with blood leads less that (sic) 10 ug/dl."

U.S. **EPA RESPONSE TO COMMENT H 68**:

(a) We thank the commentor for this comment. EPA agrees that the blood lead study, performed by the Illinois Department of Public Health (IDPH) under contract to ATSDR, should have included a separate control group. However, 'the Study', p.11, para 1, states that "Within a reasonable distance from the study site, no other small-to-medium sized towns could be identified with a housing stock of similar age and a population of similar socioeconomic status as the study area. It was, therefore, decided to recruit study participants from regions of Granite City, Madison, and Venice with similar housing stock but differing in proximity to the closed lead smelter. Since no separate control group was available, hypothesis testing comparisons in the Illinois part of the study primarily consisted of regression analyses. However, dichotomous analyses of the data were also performed by dividing the population into two groups using soil lead concentrations <500 mg/kg (<500 ppm) and $\geq$500 mg/kg ($\geq$500 ppm) as cutoff points. Regression analyses were...the more appropriate approach."

While it is useful to design a stratified sampling study so as to obtain representative samples within each stratum, it is essential that the stratification have some meaningful relationship to the hypotheses being tested. If there were only a desire to have uniform spatial representation of subjects, any number of alternate approaches could have been used, such as dividing the Madison County study area into census tracts and subtracts, or using existing political subdivisions such as separate cities, townships, and wards or taxation districts within the communities (in fact, no information about separate communities or neighborhoods is even included in the data set provided to EPA). Whether by intention or by inadvertence, stratifying the Madison County Lead Study area into concentric rings centered on the NL site has the **effect** of strongly stratifying the study by exposure gradient with respect to lead in soil and in household dust, and much more weakly with respect to building condition, lead paint, and sociodemographic variables. While other geographic subdivisions of the study area would have allowed a better separation of the effects of soil lead from the effects of other lead sources and from some of the potentially confounding sociodemographic factors, such as those described in EPA's May 23, 1994 comments on the draft IEHR/IDPH report, the use of concentric rings was highly informative. If this stratification did not provide a basis for regression modelling in which the "control" areas were the more remote parts of the Madison County Lead Study, then the validity of the study for inference about children in Madison County must be brought into question.

It should be noted that the blood lead levels reported in the IDPH study appear to include the internal "control" population as well as the target area in the community average.

(b) U.S. EPA analyses used distance from the NL site as an indicator of potential sources of lead near the site. Of all the measured variables in the data set provided to us, none is seriously confounded with distance from the NL site except for soil lead concentration. The range of soil lead concentrations in any ring is relatively small, so that soil lead and distance are relatively highly correlated with each other. The average soil lead in each ring is nearly inversely proportional to distance from the smelter site. In this regard, the soil lead distribution around the NL site looks very similar to every other lead smelter community we have studied.

(c) Neither the Madison County Lead Study area nor the vicinity of the NL site are demographically similar to major urban areas or to smaller urban areas (less than one million people). There is a significant association between blood lead and lead in household dust in the Madison County Lead Study, where most of the lead in household dust is derived from lead in soil in the areas closest to the NL site even after adjustment for demographic or behavioral factors and for the existence of deteriorating lead-based paint that was found in some of these houses. The incidence of elevated blood lead concentrations within about a quarter mile of the NL site is about 25 percent of children younger than 6 years of age, compared with about 10 percent in the distant parts of Madison County ("control" areas), and 16 percent in smaller urban areas in the NHANES III study. The difference is statistically significant. Deteriorating lead-based paint is one source of lead that is often found in older urban areas, and undoubtedly contributes some cases of elevated childhood lead exposure in Madison County Lead Study, but there is no reason to believe that the incidence of elevated blood attributable to lead paint should differ from other small urban areas. However, the proposed remediation area around the NL site contains lead sources, predominantly in soil, that pose an extra risk to young children who live there. Some children farther away from the NL site, in communities such as Eagle Park Acres or Venice Township, are exposed to other significant identifiable sources of lead, including yards or play areas contaminated by battery casing chips and by materials from the waste pile used for street repair or yard fill, which are hardly the most common lead sources in other urban areas.

The finding that "In the Study as a whole 16% of the 490 children tested had blood leads over 10ug/dl" fails to explain that this community average includes the internal "control' population as well as the target area (rings closest to the NL site).

(d) Rather than being "EPA's ideal situation", the criterion referred to here - that 95% of children under the age of six have blood lead levels less than 10 ug/dL - is the stated blood-lead "level of concern" for children which has been adopted not only by U.S.EPA, but by most federal and state health agencies and by the majority of physicians and health professionals. The Centers for Disease Control and Prevention has stated that "The goal of all lead poisoning prevention activities should be to reduce children's blood lead levels below 10 ug/dL." (Preventing Lead Poisoning in Young Children, A Statement by the Centers for Disease Control - October 1991, U.S. Department of Health and Human Services, Public Health Service, Summary, page 1) National concern is based on recent scientific evidence which shows that some adverse health effects occur in children at blood lead levels at least as low as 10 ug/dL.

COMMENT H 69; Specific Comment #3, page 6:

(a) "The EPA does not account for the effect on blood lead levels of socioeconomic status and condition of housing, but at least by implication concludes that elevated blood leads are due to soil. The EPA's own documents recognize that socioeconomic status and housing conditions can play a large part in childhood blood lead levels. ....if these factors have a significant influence on blood lead, they might account for any appearance of higher blood leads closer to the smelter."

(b) "...if these [socioeconomic factors and housing condition] are the true causes of any elevations in blood lead, then remediation of soils alone is unlikely to have a significant effect in reducing blood leads."

U.S. EPA RESPONSE TO COMMENT H 69:

(a) "Confounding" is a term that is widely used in epidemiology and other observational sciences. Confounding occurs when some third variable or factor is related both to the outcome or response being studied -- in this case, childhood Blood lead -- and to the nominal cause of the outcome, such as lead in dust or soil. As noted in our "Preliminary Assessment" of October 1994, several factors appear to match the decline in mean blood lead with increasing distance from the NL site, including decreasing soil lead and dust lead, decreasing housing age and deterioration, increasing parental education and income. These are potential confounding factors.

Confounding is a **potential** problem in this study. We have evaluated quantitatively the amount of confounding, to the extent that it can be defined internally from the data in "the Study", in the report prepared by A.H. Marcus. The behavioral and demographic covariates show some relationship to distance, but are not strong confounders. Household covariates are responsible for part of the variation in blood lead, and including demographic covariates such as race or ethnicity, parental education or home ownership in a model will generally reduce the unexplained variance in blood lead. Within each distance "rir most potential confounders such as age, mouthing behavior, parental income and education are not strongly correlated wit soil lead, but are more closely correlated with blood lead. These variables are therefore weak confounders of the relationship.

In summary, the scientific basis for the lack of serious confounding is that many of the sociodemographic and behavioral variables affect the rate of contact with or ingestion of soil, dust, paint chips, and other media, but have little relation to the amount of lead in each environmental component.

(b) As we have stated above, many of the sociodemographic and behavioral variables affect the rate of contact with or ingestion of soil, dust, paint chips, and other media, but have little relation to the amount of lead in each environmental component. There wouldn't be any lead in the child's blood without lead in some environmental medium encountered by the child, where the environmental media include food, drinking water, air, medicines and cosmetics, and accidental ingestion of soil, dust, or large paint chips. Even if the child's lead was acquired from the mother's lead exposure and passed on to the child during pregnancy or lactation, all of the lead in the child must ultimately come from some environmental source, and the behavioral and demographic variables can at most modify the amount of lead that the child has taken up from some current or historical exposure to environmental lead. Therefore, while it is useful to include some of the behavioral and sociodemographic variables in a statistical analysis because they help to explain the inter-individual variability in blood lead, they are at most modifiers of the uptake of lead from some environmental lead exposure pathway or source. Reductions in children's blood lead levels can only be achieved by reducing or removing the exposure pathway or source, and at the NL site, soil lead is a direct and a significant indirect exposure pathway.

COMMENT H 70; Specific Comment #4:

"The study followed up on those children found to have blood leads over 10 ug/dl and provided counselling parents on pathways of lead exposure. ....Rather than dismissing the potential effectiveness of this approach, the EPA should investigate this alternative... Counselling and education have been used successfully at the Bunker Hill site, for example."

U.S. EPA RESPONSE TO COMMENT H 70:

U.S. EPA does agree that education and counselling can be an effective interim intervention strategy when used for short periods of time, and EPA also uses these techniques in an attempt to reduce exposures to hazardous pollutants until more permanent remedies can be achieved. However, the effectiveness of such a lead education and counselling program cannot be demonstrated by this study, which allowed only a limited follow-up on a limited number of children, and did not provide an opportunity to investigate other plausible explanations for the decline in blood lead levels in these children.

Under CERCLA law, EPA is bound to seek permanent remedies, which protect all generations of children who might be adversely affected by Superfund site exposures. The education and counselling strategy is not likely to be a protective remedy over the long term, unless it was repeated on a periodic basis forever. New families would have to be identified for immediate intervention. Unless the intervention is reinforced constantly by additional visits, the effectiveness is likely to diminish over time. Such a program could prove to be costly, if not impossible to implement, when one considers applying such a strategy to protect all lead exposed children, whether they reside near Superfund sites or in inner-city neighborhoods. In addition, experiences from other public health intervention programs have shown that repeated interventions become less effective over time, giving EPA greater concern over the permanence of such a strategy. It is for this reason that most federal agencies, including the Centers for Disease Control and Prevention and the Department of Housing and Urban Development, as well as the state agencies, are recommending permanent solutions which have source removal as their basis.

The reviewers also refer to the successful education and counselling interventions used at the Bunker Hill site in Kellogg, Idaho. However, follow-up data indicates that children of new residents who have moved into non-abated housing after these interventions were completed very quickly became lead poisoned. The message seems to be that unless the sources of exposure are eliminated, children will continue to suffer the effects of lead poisoning. We invite the reviewers to examine the more recent data from this site.

COMMENT H 71; Specific Comment #5:

"The EPA's use of the IEUBK model to set a 500 ppm clean-up level for residential soil is contrary to the EPA's own guidance on the use of the model. The EPA' Guidance Manual states that use of the model to assess trigger levels for soil abatement at the community, regional or state level 'is discouraged, because risks cannot be estimated adequately.'"

U.S. EPA RESPONSE TO COMMENT H 71:

The Guidance Manual is correct in this regard. It appears, however, that the reviewers have not grasped the meaning of the warning provided therein. It is assumed that the reader of th Guidance Manual has read and understood Sections 1.4.4.3 and 4.2.7, which outline the methodology for performing risk estimates at the neighborhood or community level. It stresse that risk estimates of neighborhood lead exposure can best be obtained by examining the sum of the individual child risks i the area of interest. Section 4.2.7.4 explains how the calculation can be simplified by grouping households into smal cells (blocks or rings) in which soil lead levels have small defined ranges of values and exposure can be shown to be relatively homogeneous.

U.S. EPA has not set cleanup levels on a community basis. EPA has applied the IEUBK model at the individual household level to examine risks at the neighborhood level, in so far as this was possible given the limitations on the data provided to us. Near the NL smelter site, there is a sufficient level of homogeneity with respect to soil lead, both in terms of concentration and soil particle characteristics, due to the proximity to the former smelter site. Clean-up decisions have been carried out on a block-by-block basis, using house-by-house evaluations. At this scale, given the overwhelming effect of the NL site as a lead source, the requirement of homogeneity is satisfied. Therefore, the application of the IEUBK model at the NL site is consistent with the Guidance Manual.

COMMENT H 72; Specific Comment #6:

(a) "...EPA's representative admitted that they did not include lead paint in their application. ... 'Children can eat chips or strips of deteriorating lead-based paint directly from painted surfaces' ....The EPA's model ignores the contribution of lead paint, thereby overpredicting the magnitude of the contribution from soil."

(b) "The EPA cannot justify its position that its model, which attributes lead intake to soil, compares favorably to the real data from the Study because the Study participants were exposed to lead paint which the EPA did not account for. ...Footnote 2/ The comments by the Chemrisk division of McLaren Hart point out that the model overpredicts blood leads to a greater degree as it moves toward the upper percent of the data, so that at the 95th percentile blood lead levels are overpredicted by 4 ug/dl."

U.S. EPA RESPONSE TO COMMENT H 72:

(a) There seems to be a great deal of misunderstanding concerning how the lead paint is considered in the IEUBK model. The Guidance Manual provides a detailed discussion regarding the inclusion of paint in the IEUBK model in section 4.7:
"The IEUBK model..does not contain an explicit component for lead-based paint ingestion outside of the Alternate Source Option

in the Soil/Dust Menu. The correct use of the IEUBK model is to estimate geometric mean blood lead levels and distributions of blood lead levels in young children who have long-term chronic exposures to lead. It has been known that the ingestion of even tiny quantities of paint chips on a single occasion can cause serious lead intoxication. ... Since old lead-based paints can contain in excess of 50 percent lead, the child may ingest several million micrograms of lead in a single episode. The IEUBK model is not intended to address this situation. The IEUBK model is intended to address the situation where the child ingests typical quantities of household dust that have been contaminated by leaded soils and by deterioration of old lead-based paint from interior surfaces." The <u>interior household dust</u> lead contribution in the IEUBK model <u>already includes</u> paint that has fallen off the painted surface as fine particles, or has fallen off as discrete flakes or chips of paint and has been reduced to small particles in situ on the floor, carpet, furniture or other surfaces. When we say we did not include paint in the model, we mean that we did not include any direct ingestion of paint chips (the pica child scenario) in our evaluation; however the indirect contribution to the house dust concentration was included.

Our earlier comments about the role of interior lead paint in house dust must be tempered by the recent discovery that some of the dust lead concentrations **reported** in the Study contain inflated levels of lead, since the reported dust values were mathematical composites of the concentrations of fine sieved particles and of larger particles including large paint chips. The large paint chips would not be expected to adhere to a child's fingers or hands. Since the amount of lead in these chips would not be expected to be predictive of the lead in dust that most pre-school children transfer to their mouth during normal play, these large chips have generally been excluded from dust sample concentrations reported in other studies.

(b) U.S. EPA noted some deviations between observed blood lead and blood lead predictions using the IEUBK model. A large number of graphical and statistical comparisons have been made in order to understand why these deviations had occurred. The detailed report prepared by A.H. Marcus is included; the results of the EPA analyses include:

> (1) the deviation between observed and predicted blood lead concentrations was predicted better by **<u>reported</u>** dust lead concentration than by any other variable, including soil lead;
>
> (2) Very large deviations (predicted - observed > 25 ug/dl) occurred for about a dozen children who lived in households with extremely high **<u>reported</u>** dust lead concentrations (> 6000 ppm), which are believed to represent dust samples that

have been biased substantially upward by mathematically averaging the dust sample with a sample of large lead pa chips;

(3) Blood lead was also overpredicted among all children with **reported** dust lead concentrations between 1750 and 6 ppm, but to a much smaller extent (< 25 ug/dl), since some but probably not all of the dust samples were also somewha contaminated by inclusion of large paint chips;

(4) On average, the IEUBK model overestimated blood lead concentrations slightly for reported dust lead concentrations in the range of about 750 to 1750 ppm, which is believed to represent dust samples whose lead content has been biased upward to a lesser extent than the samples in (2) and (3);

(5) Blood lead was accurately predicted by the IEUBK model for reported dust lead concentrations below about 750 ppm, which corresponded roughly to reported soil lead concentrations < 900 ppm;

(6) Apart from the 10 to 12 children living in residences with very high dust lead concentration, there was only the expected weak dependence of observed blood lead on the behavioral and sociodemographic variables, so that the deviation between observed blood lead (which depended on these covariates) and predicted blood lead (which did not depend on these covariates) showed a weak relationship to, but no systematic bias from:

Child's age
Hours of outdoor play
Hours of play on the floor
Mean number of cigarettes smoked by adult residents each day
Parental education
Household income group

(7) On average, the IEUBK model underestimated blood lead concentrations in non-white children by about 1.2 ug/dl;

(8) The deviation between observed and predicted blood lead increased slightly for buildings in worse condition, but showed no systematic deviation apart from the children with very high dust leads;

(9) The large deviations between observed and predicted blood lead did not depend on the interior or exterior lead paint index (average of the product of XRF loading and paint condition);

(10) There was some tendency for the model to overpredict blood lead when the average product of interior XRF lead loading and paint condition exceeded about 5 to 10 mg Pb/cm^2, which is consistent with deviations attributable to paint-biased dust samples;

(11) Apart from the 10 to 12 children with very high reported dust lead concentrations, the model accurately predicted blood lead for dust lead loadings less than 5 mg Pb/m^2, and overpredicted slightly at dust lead loadings greater than 5 mg Pb/m^2;

(12) U.S. EPA would like to emphasize the fact that the soil lead and dust lead data reported in the IEHR/IDPH study and used in EPA reanalyses of the data represent valid measurements that can be used in a wide variety of empirical modeling exercises. These data are predictive of blood lead in pre-school children, and therefore can be useful in other risk estimation activities. However, there are some important or potentially important differences between these soil lead and dust lead data and the analogous measurements intended as input to the IEUBK Model, as indicated in the above remarks, that were apparently overlooked by the commentors.

COMMENT H 73; Specific Comment #7:

"The EPA's Preliminary Assessment section 3.2 states that it assumes a 70% soil to dust coefficient, which is understood to mean that 70% of the lead in outdoor soil would be transported into indoor dust. ....EPA's Technical Support Document supports a ratio of 28% .... we do not intend to adopt the ratio of 0.28 as being correct. Instead we question how EPA can support the use of 0.70"

U.S. EPA RESPONSE TO COMMENT H 73:

U.S EPA has extensively analysed the data from the Madison County Lead Study in order to assess an appropriate site-specific value. One of the complicating factors is that some of the the higher dust lead concentrations reported in that study are mathematical composites of lead concentrations in fine particles (as was intended for input into the IEUBK Lead Model), and concentrations of lead in paint chips (which was not intended, and has not been used in other applications). Different analyses lead to somewhat different estimates, with some (from the structural equation analyses) in the range of 0.7 to 0.9, and others (from regression analyses) somewhat lower, with a value of 0.385 estimated for the whole data set. Values close to 0.7 provide a good prediction of blood lead concentrations observed in the Madison County Lead Study, better in fact than the reported concentrations which may be biased by inclusion of lead paint chips. Application of different site-specific estimates finds that there is only mo t sensitivity of a soil lead cleanup value to the value selecte for this coefficient within the maximum range of values sugge d by site-specific analyses. The value of 0.70 implies a soil d cleanup value of 350 ppm; even a much lower value of 0.20 sti implies a soil lead cleanup level of 520 ppm.

COMMENT H 74; Specific Comment #8:

"A limited study to speciate the lead found in the dust and soil samples should be conducted to assess with more precision and scientific certainty the true source of the lead which has been found in the surveys. There is good reason to believe that were such a study conducted, it would reveal that elevated lead levels in house dust are due primarily to deteriorating lead paint."

U.S. EPA RESPONSE TO COMMENT H 74:

Conversations with John Drexler, Colorado State University, who has provided the speciation data for a number of Large Area Lead sites, indicated that speciation is based on a number of data observations, including particle size, stiochiometry, morphology, frequency of occurrence and relative metal mass. Both paint dust and smelter dust have similar particle sizes, stiochiometry and morphology as both readily oxidize to lead oxide. Thus it is likely to be difficult to distinguish lead dust originating from paint from lead dust originating from smelter emissions. We believe that while speciation studies may be useful in characterizing mine waste, these studies would not provide much meaningful data at this site.

RESPONSE TO COMMENTS

Section 3: McLaren Hart Comments on the Proposed Plan, Record Review, and Exposure Study

Comments on the Proposed Plan, #1

COMMENT H 75:

"In developing a residential soil cleanup level for the NL Industries/Taracorp site, the U.S. EPA did not fully take into account the potential for sources of lead other than soil to impact blood lead levels."

U.S. EPA RESPONSE TO COMMENT H 75:

U.S. EPA is in full agreement with the contents of the "Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities", OSWER Directive #9355.4-12, July 14, 1994.

The Guidance Manual for the IEUBK model provides a detailed discussion regarding the inclusion of paint in the IEUBK model in section 4.7: "The IEUBK model..does not contain an explicit component for lead-based paint ingestion outside of the Alternate Source Option in the Soil/Dust Menu. The correct use of the IEUBK model is to estimate geometric mean blood lead levels and distributions of blood lead levels in young children who have long-term chronic exposures to lead. It has been known that the ingestion of even tiny quantities of paint chips on a single occasion can cause serious lead intoxication. ... Since old lead-based paints can contain in excess of 50 percent lead, the child may ingest several million micrograms of lead in a single episode. The IEUBK model is not intended to address this situation. The IEUBK model is intended to address the situation where the child ingests typical quantities of household dust that have been contaminated by leaded soils and by deterioration of old lead-based paint from interior surfaces." The <u>interior household dust</u> lead contribution in the IEUBK model <u>already includes</u> paint that has fallen off painted surfaces as fine particles, or has fallen off as discrete flakes or chips of paint and has been reduced to small particles in situ on the floor, carpet, furniture or other surfaces.

When U.S. EPA has said that we did not include paint in the model, we mean that we did not include any direct ingestion of paint chips (the pica child scenario) in our evaluation, as we do not believe that Potentially Responsible Parties would care to or need to clean up soil to protect the pica child. However the indirect contribution of paint to the house dust concentration was included in the evaluation. We have also included a sensitivity analysis using a range of values for the contribution of lead-contaminated soil to household dust (0.29 to 0.70); these values suggest a soil remediation level of 340 - 480 ppm, or a soil lead cleanup value of 400 to 500 ppm. USEPA did not use the attributable risk method to determine the soil lead cleanup level for the NL Industries site (the attributable risk method calculates the additional risk posed on each child on a house-by-house basis, given the any additional exposure to lead from other sources, including paint) as Region 5 believes that it is inappropriate to adjust the soil cleanup value downward to protect for other sources of exposure. Region 5 prefers to use an integrated, cross-agency approach to address potential multiple sources of contaminant exposure and has pursued this approach at the NL Industries site.

COMMENT H 76:

"Further, the USEPA did not fully evaluate the potential that remediation of soils to the selected residential soil cleanup level would not result in significantly decreased blood lead levels." The commentors also refer to the USEPA's Urban Soil Lead Abatement Demonstration Project in Baltimore, MD to support their position.

U.S. EPA RESPONSE TO COMMENT H 76:

The effectiveness of soil lead remediation has been repeatedl demonstrated in public presentations and peer-reviewed publications. USEPA notes that the commentors chose to ignore this data, which includes von Lindern's report of reductions in blood lea levels at the Bunker Hill, Idaho site (item 105 in the supplement to the Administrative Record) and the Aschengrau et. al. report on the Boston Lead-In-Soil Demonstration Project (Environ. Res. 67, 125-148, 1994). More recently, similar reductions in blood lead levels have been reported by the New Mexico Department of Public Health, after soil removal at the smelter site in Socorro, NM (J. Environ, Health. 57, 8-14, 1995). All studies report reductions of several ug/dL in the <u>mean</u> blood lead levels of children - a significant drop.

In addition, although the Urban Soil Lead Abatement Demonstration Project report has not completed final review, the results of the study to date demonstrate a relationship between elevated soil lead levels and elevated blood lead levels and are consistent with USEPA's current guidance that soil lead levels below the current screening level of 400 ppm (the level below which further study or action is generally not warranted) are unlikely to present a health risk to children. In Boston, where preabatement lead levels in soil were greatest and averaged approximately 2500 ppm, the impact of soil lead reductions on house dust could be measured even after 1 year when lead-based paint was also stabilized, and even greater reductions in blood lead concentrations were found 2 years after the original soil abatement. The combined results from both phases of the study suggest that a soil lead reduction of 2060 ppm is associated with a 2.25 to 2.70 ug/dL decline in <u>mean</u> blood lead level. The low levels of soil recontamination after 1 to 2 years after abatement indicate that remediation is persistent. In Baltimore and Cincinnati, where most preabatement soil lead levels were close to the Superfund screening level, the individual studies did not identify a relationship between reductions in soil lead and reductions in blood lead in urban neighborhoods where soil lead levels originally averaged around 500 ppm. Reanalysis by USEPA using different statistical methods, however, found that reductions of lead in house dust in each city produced corresponding reductions in blood lead, a relationship that is consistent with findings in Boston.

U.S. EPA has preliminarily interpreted the results of the study to indicate that interruption of the pathways by which children are exposed to dust produces a reduction in blood lead levels. Abatement of lead-contaminated soil in areas with higher soil concentration is associated with declines in blood lead levels. In those areas with soil lead levels close to the Superfund screening level, the relationship between reductions in soil lead levels and reductions in blood lead levels was not identified, although a relationship between reduction in dust lead levels and reduction in blood lead levels was preliminarily indicated. U.S. EPA has yet to complete the peer review on the study.

Comments on the Proposed Plan, #2

COMMENT H 77:

The U.S. EPA's actions at the Site, including the selection of the residential soil lead cleanup level and the use of the IEUBK Model in its selection, were inconsistent with U.S. EPA's own most recent guidance for soil lead cleanup levels and for the application of the model."

U.S. EPA RESPONSE TO H 77:

The response to COMMENT H 75 has already addressed the major issues raised under this comment. In their reference to the Bunker Hill site, the commentors failed to explain that the site encompasses a 21 square mile area and includes five cities, or that the use of the residential soil lead action level of 1000 ppm will result in the ultimate cleanup of 85-90% of the individual yards in those communities nearest the smelter. Public parcels, including parks, playgrounds and right-of-way areas were remediated immediately and dust control measures have been in place for eight years while the remediation is continuing. An expedited response action level of 1200 ppm was chosen for the Butte, MT site, where the lead concentration level was used to limit the depth of the cleanup, not the number of yards to be remediated; this is not a final cleanup level. The commentors have also failed to acknowledge that cleanup levels well below 1000 ppm have been chosen for other smelter sites across the country, including 500 ppm for the Midvale, UT site and 700 ppm for the East Helena site.

U.S. EPA noted that at most other lead sites, the responsible parties have agreed to removal actions on the most contaminated properties to protect the health of the children, while at the Granite City site the health of the children does not seem to be a consideration of the responsible parties.

Comments on the Proposed Plan, #3

COMMENT H 78:

"Even if the model is used for evaluation of a residential soil cleanup level, USEPA's application of the model for this purpose is flawed."

U.S. EPA RESPONSE TO H 78:

U.S. EPA's application of the model for evaluation of a residential soil cleanup level is not flawed as the data used in the model evaluation was used correctly. Not all inputs can be varied when a large data set is evaluated using the batch mode enhancement. However, this does not mean that all inputs to the model were not carefully considered, as implied by the comment that "had the USEPA considered the relative degree of vegetation cover, the blood lead levels predicted by the model would likely have been lower." This comment seems to represent "wishful thinking", rather than actuality. While the data set provided to USEPA contained no information on the condition of each yard, observations by contract staff and USEPA personnel onsite indicated that many of the yards closest to the smelter appeared to contain bare spots, an observation consistent with the comment that homes nearest the smelter were more likely to be poorly maintained. Even the U.S. EPA regional representative quoted in the comment, has seen the site residential areas in wet times when the residential yards had some degree of cover and in dry years when large bare spots were more common.

COMMENT H 79:

....."the data utilized has not been included in the public record."

U.S. EPA RESPONSE TO COMMENT H 79:

Regarding the absence of the data base in the public record, USEPA has stated that we used the data collected for the Madison County Lead Exposure Study in our analyses. The data was used in a manner which protects the confidentiality of the residents of the Madison County area. USEPA does not own the data base, which was provided to them for this purpose by the Illinois Department of Public Health (IDPH). IDPH has provided the data to a number of other parties for similar analyses. USEPA is, therefore, not legally able to include the data in the public record. Interested parties may request the data from IDPH or its subcontractor, IEHR.

Additional comments regarding the running of the model and the Ginsberg and Hoffnagle (1995) comments have been addressed in the response specifically prepared for the TRC Environmental Corporation review. Only original comments by McLaren/Hart Environmental Engineering Corporation will be considered here.

Comments on the Proposed Plan, #4:

COMMENT H 80:

"If the IEUBK model is run utilizing site-specific parameters in evaluation of post-abatement conditions using ranges of soil lead cleanup levels, the results predict that addressing soil alone will not result in the USEPA's objective of less than 5 percent of children exceeding 10 ug/dl blood lead."

U.S. EPA RESPONSE TO COMMENT H 80:

The Ginsberg and Hoffnagle (1995) comments have already been addressed in the response specifically prepared for the TRC Environmental Corporation review. Only original comments by McLaren/Hart Environmental Engineering Corporation will be considered here. However, the commentors seem to be confusing the need for soil lead cleanup in the area of Granite City closest to the smelter with an all-source, area-wide Madison County cleanup which encompasses Granite City, Madison and Venice. USEPA did not seek any remedial action for properties at distance from the smelter where the soil lead levels are less than 500 ppm or battery casing fill was not evident.

Comments on the Proposed Plan, #5:

COMMENT H 81:

"The technical documents placed in the Administrative Record do not support the 500 ppm cleanup level for lead in soils as a mechanism for mitigating potential health risks associated with the Site. However, several of the documents do support the need to evaluate and abate sources of lead in addition to soil to reduce blood lead levels."

U.S. EPA RESPONSE TO COMMENT H 81:

The comment refers to a review of the Administrative Record prepared by McLaren/Hart and submitted as a separate document entitled "Review of Public Record Documents for the NL Industries/TaraCorp Site". This document has its own response summary; therefore, there is no need to repeat that response here.

Likewise, the following documents containing solicited expert review were afforded their own response summaries. These will not be repeated here.

-"Madison County Lead Exposure Study, Granite City, Illinois," by R. Kimbrough, M. LeVois, and D. Webb (Illinois Department of Public Health);

"Comments on Madison County Lead Exposure Study, Granite City, Illinois," by A.H. Marcus, K. Hogan, P. White, and P. Van Leeuwen (USEPA);

Response to Comments of the U.S.EPA Reviewers Regarding the Granite City Lead Study Draft Report," by M. LeVois (Illinois Department of Public Health):
and

-"Preliminary Assessment of Data from the Madison County Lead Study and Implications for Remediation of Lead-Contaminated Soil," by A.H. Marcus (U.S. EPA).

Comments to Proposed Plan, #6:

COMMENT H 82:

"While U.S. EPA was relying on current guidance at the time of the ROD in selection of the residential soil lead cleanup level, since that time, the U.S. EPA has taken a more site-specific approach to the selection of cleanup levels at similar sites. In some cases, this has resulted in the selection of soil lead cleanup levels substantially higher than the 500 ppm level set for the NL Industries/TaraCorp Site."

U.S. EPA RESPONSE TO COMMENT H 82:

In their reference to the Bunker Hill site, the commentors have failed to explain that the site encompasses a 21 square mile area and includes five cities, or that the use of the residential soil lead action level of 1000 ppm will result in the ultimate cleanup of 85-90% of the individual yards in those communities nearest the smelter. Public parcels, including parks, playgrounds and right-of-way areas were remediated immediately and dust control measures have been in place for eight years while the remediation is continuing. An expedited response action level of 1200 ppm was chosen for the Butte, MT site, where the lead concentration level was used to limit the depth of the cleanup, not the number of yards to be remediated; this is not a final cleanup level. The commentors have also failed to acknowledge that cleanup levels well below 1000 ppm have been chosen for other smelter sites across the country, including 500 ppm for the Midvale, UT site and 700 ppm for the East Helena site.

U.S. EPA does not agree with the comment that "if the residential soil cleanup levels for the NL Industries/Taracorp Site were developed following the current guidance, a higher residential soil lead cleanup level would likely be selected".
U.S. EPA has conducted an indepth site-specific review of the NL Industries/TaraCorp Site, submitted initially as a preliminary report "Preliminary Assessment of Data from the Madison County Lead Study and Implications for Remediation of Lead-Contaminated Soil," by A.H. Marcus. The final document is submitted with this comment package as "Statistical Analyses of Data from the Madison County Lead Study and Implications for Remediation of Lead-

Contaminated Soil," by A.H. Marcus. Rather than support a higher residential soil lead cleanup level, this evaluation suggests a soil remediation in the range of 400 to 500 ppm would be more appropriate to protect the area children from adverse health effects, when all site-specific data is considered. U.S. EPA did not use the attributable risk method to determine the soil lead cleanup level for the NL Industries/Taracorp site (the attributable risk method calculates the additional risk posed on each child on a house-by-house basis, given any additional exposure to lead from other sources, including paint) as Region 5 believes that it is inappropriate to adjust the soil cleanup value downward to protect for other sources of exposure. Region 5 does believe that an integrated, cross-agency approach is necessary in order to address potential multiple sources of contaminant exposure and has pursued this approach at the NL Industries/Taracorp site.

RESPONSE TO COMMENTS

<u>Section 3: McLaren/Hart Comments: Exhibit A Review of the Public Records Documents</u>

COMMENT H 83 (Comment 1); Executive Summary, page i, para. 2:

"No document reviewed supported or demonstrated that soil lead cleanup levels of 500 ppm would significantly reduce lead in blood"

U.S. EPA RESPONSE TO COMMENT H 83:

A number of reports included in the record document a significant reduction in blood lead levels in children with reductions in soil lead levels, including the von Lindern report "Reducing Children's Blood Lead Levels at the Bunker Hill Superfund Site in Northern Idaho, USA through Health Intervention and Soil/Dust Source Control Measures", the reports from the U.S. EPA Urban Soil Lead Abatement Demonstration Project, the more recent follow-up report on the Boston study by Ashengrau et al. "The Impact of Soil Lead Abatement on Urban Children's Blood Lead Levels: Phase II Results from the Boston Lead-In-Soil Demonstration Project" (recently added), the report on the cleanup at the Socorro, NM smelter site by Edison et al. "Blood Lead Levels and Remediation of an Abandoned Smelter Site" (recently added), etc.

The commentors do not distinguish between soil cleanup goals used for overall site remediation, soil lead trigger levels, used to prioritize the remediation action to the most contaminated properties, and soil lead action levels which were used to limit the depth of the soil removal without diminishing the number of properties to be remediated. U.S. EPA suggests that the commentors review the use of the soil lead remediation value and not quoting "ppms". Using consistent methodology, site-specific considerations will result in different cleanup levels for different sites.

COMMENT H 84 (Comment 2); **Executive** Summary, P. i, para.2: "One of the documents **reviewed** indicated only a slight increase in PbB (1.25 ug PB/dL of **blood**) was associated with a 1000 mg/kg increase in soil **concentrations** for an inactive smelter site based on a study **conducted in** Midvale, Utah" Assuming an average background PbB in a child is 5 ug/dL, the results from the Midvale study **suggest** that a soil concentration of 4000 mg/kg would be required to **reach** a blood lead concentration of 10 ug/dL."

U.S. EPA RESPONSE TO COMMENT H 84:

U.S. EPA believes that **the** commentors mean that the study found a decrease of 1.25 ug/dL in **the** blood lead levels of children in the study associated **with a** 1000 mg/kg decrease in soil lead concentrations. **This is a sizeable** and **significant decrease** in the children's blood lead **levels**; the report is addressing a reduction in the mean blood level, not a reduction in the **number** of children **who exceed the 10 ug/dl** level-of-concern. If in fact, the allowable soil **lead** concentration was to be raised to the 4000 mg/kg level **suggested** by the commentors, greater than 50% of the children would **be** likely to have blood lead levels which exceed 10 ug/dL (in **contrast** to the 5% cut-point established by U.S. **EPA for** protection of children), and some children would greatly **exceed** the mean value. For the latter group, the prognosis would likely be chelation treatment, if not coma or even death. U.S. **EPA** does not find such a suggestion to be credible.

COMMENT H 85 (Comment 3); **Executive** Summary, p.i, para. 3:

"Overall, the documents **reviewed** do not support the recommendation of a 500 **ppm** cleanup level for lead in residential soils as a **mechanism** for mitigating potential health risks associated with elevated **blood** lead levels in children living in the vicinity of the **NL Industries/Taracorp** Site. The majority of the information **reviewed supports** the concept that cleanup levels should be **determined for each site** using site-specific data along with available data **analysis** techniques and current toxicological information to **develop an appropriate** cleanup level or Preliminary Remediation **Goal** (PRG) based upon protecting human-health and the environment.........."

U.S. EPA RESPONSE TO COMMENT H 85:

U.S. EPA agrees, in part, with this assessment of the Public Record, but it is apparent that the McLaren/Hart reviewers have misinterpreted the material provided from other smelter sites. They erroneously concluded that the information provided did not support the recommendation of a 500 ppm (or less) cleanup level for lead in soil at the NL Industries/Taracorp site. U.S. EPA agrees that only a Preliminary assessment of the data from the Madison County Lead Study was available previously. A more extensive presentation of the data analysis has been prepared by A.H. Marcus in the accompanying document "Statistical Analyses of Data from the Madison County Lead Study and Implications for Remediation of Lead-Contaminated Soil"; the conclusions of the two documents are identical. They present a series of indepth analyses of the site-specific data for the NL Industries/Taracorp site and fully support U.S. EPA's selection of a soil lead cleanup level in the range of 400 to 500 ppm to protect area children from the adverse health effects of lead exposure.

U.S. EPA believes that the Administrative Record supports the following conclusions:

a) The Administrative Record contains documents which support the recommendation of a 500 ppm soil lead cleanup level for the Site;

b) The Administrative Record contains comparisons with other similar sites which indicate that similar soil lead cleanup levels have been effective in reducing blood lead levels in children. Although a range of soil lead remediation values were used at these sites, some values were trigger levels or action levels used to prioritize removal and remedial action, not final cleanup values or PRGs. The use of action levels greater than 500 ppm did not in general restrict the number of yards scheduled for cleanup;

c) The Administrative Record contains documents which support the concept that site-specific data and current toxicological information should be used to develop the cleanup level or PRG for the site. The Marcus report "Statistical Analyses of Data from the Madison County Lead Study and Implications for Remediation of Lead-Contaminated Soil", the Illinois Department of Public Health report "Madison County Lead Exposure Study, Granite City, Illinois" and the review of this study by Marcus et al. "Comments on the Madison County Lead Exposure Study, Granite City, Illinois" have all been used to evaluate the lead exposure to children at the NL Industries/Taracorp site;

d) The Administrative Record contains documents on toxicological issues, including studies which characterize the human health effects of lead exposure in adults and children and studies which discuss multiple sources of lead exposure. These documents provide a general background on lead exposure and toxicity, which is useful for evaluating the remedial strategy at the NL Industries/Taracorp site, as well as providing much information to residents and students in the Madison County area;

e) The Administrative Record includes documents which review the use of various biomarkers and tests which can be used to assess the body burden of lead in adults and children. Many of these documents have been included in response to questions from Madison County residents regarding their past lead exposures, as they provide better methods of assessing the lead body burden in adults than do blood lead levels which reflect only recent exposure.

U.S. EPA noted the comment that Needleman's studies should be viewed with caution, stating that the researcher was "investigated for misuse and manipulation of study data". U.S. EPA regards these studies as valid, noting that not only was this researcher not the first to be threatened by the lead industry, but that after extensive review of his work and two formal hearings, "no evidence of fraud, falsification or plagiarism" or evidence suggesting scientific misconduct was found in Needleman's work;

f) The Administrative Record includes documents which review much of the available data on lead bioavailability. These documents illustrate that the highest relationship between blood lead and soil lead was seen at smelter sites, suggesting that the lead contributions to soil from such sites is more bioavailable than waste from some other lead operations. The documents included also suggest that the rat may not be as appropriate a model for bioavailability studies as the mini-pig and illustrate the variation in bioavailability which can be expected when animal doses of lead greatly exceed the doses of lead that children may ingest. The mini-pig studies clearly show that ingestion of lead in residential soil produces elevated blood lead levels in young pigs.

In summary, the toxicological documents provided in the Administrative Record support the setting of a site-specific soil lead cleanup level, 500 ppm in the case of the NL Industries/Taracorp Site, which will result in the removal of surface soil sufficient to reduce the risk of elevated blood lead in children who may come in contact with the soil, both by direct ingestion of soil and indirect ingestion of dust. The documents characterize the adverse health effects of lead exposure in children and adults, and demonstrate that soil lead cleanup has been an effective strategy for reducing the blood lead levels in children.

RESPONSE TO McLAREN AND HART EXHIBIT B

COMMENT H 86(MH-B1), p. 1, bottom 6 lines, and p. 2, top 2 lines:

"Based on the analyses performed in the original study and barring changes in interpretation due to additional treatment of the data:

- The lead levels in children's blood in the Madison County study area do not indicate an imminent public health problem.
- Soil remediation is not likely to significantly reduce blood lead levels in children, in general.
- Soil remediation is not likely to significantly reduce blood lead levels in children with "elevated" levels of blood lead."

U.S. EPA RESPONSE TO COMMENT H 86:

EPA reanalyses suggest that many of the conclusions and interpretations in the IEHR/IDPH draft report of February, 1994, may require substantial revision. For these three main points:

- Certain areas of Madison County near the NL site show substantially elevated blood lead concentrations, and substantially elevated percentages of children with elevated blood lead, compared to most other parts of Madison County included in the study. Reanalyses show that these elevated blood lead concentrations are more probably attributable to elevated concentrations of lead in soil and resulting elevations of lead in household dust than to lead-based paint or to other sources.
- Soil remediation has been very effective in some other locations where soil lead is a demonstrable significant source of blood lead in children, and where recontamination of the residence after abatement has been effectively controlled.
- Soil lead remediation will address the primary source of lead exposure for the children near the NL site.

COMMENT H 87(MH-B2), p. 3, lines 7-10:

"... if generalizing to the community is important, then some demonstration is required that the participants are similar to or different from the nonparticipants as defined by variables in the study ..."

U.S. EPA RESPONSE TO COMMENT H 87:

U.S. EPA agrees, and found the IEHR/IDPH database deficient in this regard.

COMMENT H 88 (MH-B3), p. 3, lines 12-24:

"... the presentation of regression results in the Exposure Study is somewhat incomplete, and there are some analyses not presented that could be informative. ... more emphasis on hierarchical regressions ... additional questions could be posed an answered, such as what percent of variance is explained upon adding lead in paint and condition of residence when soil composition [sic] is in the model?"

U.S. EPA RESPONSE TO COMMENT H 88:

The EPA reanalyses of the data have provided a very complete and comprehensive assessment of hierarchical regression models analogous to the model cited in the IEHR/IDPH study. To briefly summarize EPA's findings: The baseline model used by IEHR/IDPH is inappropriate. Whether or not that model or some more appropriate model is used, the additional variable that is most predictive of blood lead beyond the baseline model is dust lead loading, which increases the "explained" variance by 8 to 14 percent; soil lead increases "explained" variance by 3 or 4 percent, and even explains an additional 1 or 2 percent of variance when dust lead is included in the model. Lead-based paint never explains more than an additional 1 percent of variance, usually much less than 1 percent, and is always less predictive of blood lead than is soil lead. Building condition is also very predictive of blood lead, but is not very highly confounded with environmental lead so that the building condition effect can be separated from the effects of environmental lead exposures on blood lead. The missing value imputation used in the IEHR/IDPH report is much less predictive than several other imputations evaluated by EPA, and the estimated effect of building condition is actually attenuated by the IEHR/IDPH approach.

COMMENT H 89 (MH-B4), p. 3, last 4 lines:

"Inclusion of some regression diagnostics would be very helpful ... there is no way to verify that the regressions were well-behaved and satisfied the required assumptions."

U.S. EPA RESPONSE TO COMMENT H 89:

U.S. EPA agrees that the IEHR/IDPH report was significantly deficient in regression diagnostics. The EPA reanalyses examined regression residuals and calculated routine diagnostics for outliers and for influential observations. A group of observations with high dust lead concentrations was identified as highly influential, which had already been suggested by the non-standard protocols by which dust lead concentration data were reported. Additional analyses were run with subsets of the data omitting these influential observations, but there was relatively little change in results of the analyses.

COMMENT H 90 (MH-B5), p. 4, first para.:

"It appears that age is a proxy for exposure and is not pathway-specific (i.e., not specific to paint or soil). Therefore it should be included somehow in the modeling either as a continuous or categorical predictor, and using a nonlinear form ..."

U.S. EPA RESPONSE TO COMMENT H 90:

EPA used age as a categorical predictor in regression models, with indicator variables for one-year intervals through age 3 years, but grouping together ages 4-6 whose responses were not significantly different. We also used quadratic models in some regression and structural equation models, which reduced the number of free parameters to be estimated.

COMMENT H 91 (MH-B6), p. 4, second para.:

The Exposure Study does not include terms for interactions among variables within the regression models. ..."

U.S. EPA RESPONSE TO COMMENT H 91:

The EPA reanalyses examined many possible interaction terms in regression models for blood lead, dust lead, and soil lead. Very few interactions were statistically significant, except for an age-dependent interaction with dust lead and soil lead as predictors of blood lead. The IEHR/IDPH report did not show any awareness of the possible role of interaction terms.

COMMENT H 92 (MH-B7. Page 4, third para.):

"... Distance from the smelter ... is a crude predictor. ... use of distance in the modeling is a minor consideration when actual soil data is available. ... distance ... could not be a complete exposure proxy because children do not reside exclusively at any particular distance from the Site."

U.S. EPA RESPONSE TO COMMENT H 92:

It is worth noting that the linear correlation between the logarithm of soil lead and the logarithm of distance is one of the strongest simple correlations in the Madison County data set. However, distance was not used in most of the regression analyses for blood lead that were carried out by EPA. There was a very strong relationship between soil lead and the inverse of the distance of the residence from the NL Site, much stronger even than the relationship between soil lead and deteriorating exterior lead-based paint. When the distance component of soil lead was used in an environmental pathway model, there was little additional dependence of dust lead or blood lead on distance, apart from that which was accounted for by directly relevant socio-demographic and environmental variables.

The hypothesis that the child's residence is the primary source of lead exposure is generally accepted, even though some additional exposure occurs outside the home. This hypothesis is consistent with the fact that household dust lead loading is the single best predictor of blood lead in the Madison County study, explaining by itself 15 to 20 percent of the variance in the logarithm of blood lead. The Madison County data are well explained by a simple plausible inter-related model for lead pathways that is qualitatively the same as seen at all other sites with lead point sources such as smelters: (1) lead in soil in the residential yard is related to distance from the point source and to exterior lead-based paint; (2) lead in household dust is related to lead in soil, to lead in interior lead-based paint, and to other relatively minor sources; (3) blood lead is strongly related to lead in household dust in most pre-school children, and to some extent to lead in yard soil; (4) blood lead is also related to other sources such as drinking water, and is modified by socio-demographic and individual behavioral factors. The role of distance from the site is clearly defined. EPA showed that distance from the NL site is related to a variety of factors; this provided convenient graphical displays to put these diverse factors on a common scale, as a supplement to bivariate and multivariate analyses in EPA's reanalyses of the data.

COMMENT H 93 (MH-B8, p, 4, 4-5 lines from bottom):

"... there is not a problem with average or typical blood lead levels."

U.S. EPA RESPONSE TO COMMENT H 93:

EPA's concern is that comparison of average or typical blood lead concentrations does not identify the real problem, which is the high incidence of children with elevated blood lead concentrations near the NL site.

COMMENT H 94 (MH-B9, p. 5, lines 13-18):

"... soil remediation is unlikely to substantially affect the variance in blood lead levels in order to meet the USEPA target, the entire distribution of blood lead levels would need to be shifted towards lower values. ... A better use of resources would be to target and identify those factors which result in blood lead levels near or exceeding clinically significant values."

U.S. EPA RESPONSE TO COMMENT H 94 :

The commentor appears to have misinterpreted the basis for EPA's risk estimation procedures, since any discussion of community percentages is irrelevant for remediation decisions which are applied on a house-by-house or yard-by-yard basis. The criterion to be applied is that for children living at a particular residence, there should not be more than a 5 percent risk that the child will have blood lead exceeding the health-based blood lead level of concern of 10 ug/dl. In communities such as Granite City, where a large number of properties on the same block may have high soil lead concentrations, there is a high potential for childhood exposure even when the child's own residence may not be as highly contaminated, so that it would be appropriate to carry out soil remediation on a larger scale such as a city block. As noted in the EPA assessments, a much higher incidence of children with elevated blood lead concentration is indeed found in houses with higher soil lead and soil-derived dust lead concentrations in the areas of Madison County closest to the NL site, which is why these areas have been targeted for remediation.

COMMENT H 95 (MH-B10), p. 6, lines 4-5:

"At the 95th percentile, blood lead levels are overpredicted by the model ..."

U.S. EPA RESPONSE TO COMMENT H 95 :

The commentor should note that this issue has been discussed in detail in the EPA reanalyses. The empirical distribution of predicted blood lead uses no distributional assumptions and is based on application of the IEUBK model with site-specific input data. The output of the model is the predicted (or best estimate) of blood lead. The over-prediction is attributable to the use of reported dust lead concentration data that were contaminated by large paint chips in a number of cases; while this method for reporting dust lead is informative, it is not the standard method used as input for the IEUBK model, which is the lead concentration in fine particles. This potential biasing factor in the input data for the IEUBK model requires adjustment.

COMMENT H 96 (MH-B11), p. 6, lines 12-17:

"First, 'very good fit' is a subjective judgement ... not a strong relationship along the unit slope line..."

U.S. EPA RESPONSE TO COMMENT H 96 :

Large inter-individual differences in behavior and exposure tend to mask the overall goodness of fit, and alternative methods such as used in EPA reanalyses are more appropriate. The mean difference between observed and predicted blood lead is less than 3 ug/dl for soil lead less than 2000 and dust lead less than 10,000 ppm, using estimated rather than observed dust lead (see Response COMMENT H95 (MH-B10)).

COMMENT H 97 (MH-B12), p. 6, lines 17-21:

"Second, even if there were a 'very good fit', this fact alone would not strongly support the 70 percent soil-to-dust coefficient being correct in the IEUBK model. That 70 percent gives the best fit under the circumstances does not mean that 70 percent is the true value."

U.S. EPA RESPONSE TO COMMENT H 97 :

EPA has carried out additional analyses to assess a wider range of soil-to-dust coefficients and lead paint contributions to lead in household dust.

COMMENT H 98 (MH-B13), p. 7, first para.:

"... Structural equation modeling could check the sequential, model-based significance of many of the measured variables. ... in the event that a plausible model can be developed it does not implicitly affirm causal relationships or overall validity or reliability of the modeling approach."

U.S. EPA RESPONSE TO COMMENT H 98:

The last comment could be applied generally to any use of mathematical models as a basis for scientific inference. In fact, the environmental pathways have been determined by physical and biological methods such as experimental interventions on lead exposure pathways, and by use of stable lead isotopes as source tracers. EPA's reanalyses have found that the structural models for the Madison County study are rather similar to models developed from data at other sites. Any decision about remedial action at a lead-contaminated site, whether the action is soil removal or no action, depends on some conceptual model of lead exposure for young children who reside there. EPA has developed mathematical models that are biologically and physically plausible as an explicit and formal basis for evaluating alternative remediation decisions, and to assist in the decision-making process. While the predictiveness of such models can never be used to "prove" that they are correct, repeated successful applications of a modeling approach certainly lend credibility to the use of the model.

ATTACHMENT 3

NL INDUSTRIES/ TARACORP
GRANITE CITY, ILLINOIS
RESPONSIVENESS SUMMARY REGARDING TARACORP PILE, GROUND WATER, AND REMOTE FILL AREAS

I. RESPONSIVENESS SUMMARY OVERVIEW

The overview of this responsiveness summary (RS) is the same as that for the residential soil cleanup (located in Section I of Attachment 2), with the following exception:

> Due to new information discovered during the remedial design and remedial action for the NL Site, U.S. EPA decided to reevaluate the remedy specified in the March 30, 1990, Record of Decision (ROD) with respect to the Taracorp pile, the newly discovered ground water contamination in the area of the Taracorp pile, and the greatly increased number of remote fill areas requiring remediation. Accordingly, on February 17, 1995, U.S. EPA released to the public, a Proposed Plan and a Second Addendum to the Feasibility Study. U.S. EPA held a public comment period regarding the proposed remedies for the remote fill areas with possible paving uses (driveways, alleys, and parking lots) and the Taracorp pile and associated ground water contamination from February 17 to April 19, 1995. A public meeting was held at the Granite City Township Hall, Granite City, Illinois, on March 6, 1995.

The purpose of this responsiveness summary is to document the Agency's responses to question, concerns, and comments received during the comment period and during the public hearing. These comments and concerns were evaluated prior to selection of the remedial action for the site.

A complete copy of the Administrative Record, and other pertinent information is available at the Granite City Public Library, Granite City, Illinois, and at the U.S. EPA office in Chicago, Illinois.

II. BACKGROUND ON COMMUNITY INVOLVEMENT

Community Relations Plan Summary

The Community Relations Plan (CRP) for the site was prepared by the U.S. EPA, who is responsible for community relations and remedial activities at the Site under CERCLA.

1. The cost differential between capping and the least expensive pile removal alternative is approximately $30 million,

2. Capping is preferred over the pile removal alternative based upon short-term effectiveness of the remedy. Movement of the pile would generate dust which would impact human health and the environment. Based upon test trenching in the Taracorp pile, U.S. EPA finds that conventional dust suppression methods do not control lead dust to acceptable levels. Hence, a more sophisticated system of dust suppression will likely be needed to achieve the National Ambient Quality Standard for lead during pile remediation. Given this difficulty, the alternative involving the least potential for dust generation, i.e. capping, is preferred,

3. Once implemented, capping and removal of the pile are essentially equal in terms of long-term effectiveness such as prevention of direct contact with and inhalation of contaminants from the Taracorp pile,

4. Removal of the Taracorp pile will provide superior protection to capping in terms of reduction of ground water contamination,

5. There are no known drinking water users of ground water downgradient from the Taracorp pile/main industrial area of the Site. Illinois EPA and U.S. EPA conducted extensive surveys to verify this fact. Drinking water in the area of the Site is obtained from the Mississippi River, and

6. In summary, U.S. EPA cannot justify the expenditure of an additional $30 million for a Taracorp pile removal alternative when such an alternative will only increase the potential for generation of dust during its implementation (and thus possible recontamination of remediated residential yards near the pile) and the only tangible benefit from a pile removal alternative would be to decrease ground water contamination in an area where there are no known users of ground water for drinking water purposes (i.e. receptors).

COMMENT 2: One commentor requested that U.S. EPA stop digging (excavating residential soils) in Granite City, while another expressed support for U.S. EPA's approach of excavating residential soils as a priority item, prior to remediating the Taracorp pile.

U.S. EPA RESPONSE TO COMMENT 2: U.S. EPA responded to these piezometers would be installed to adequately monitor the cone of depression that the pumping well would develop.

However, this will need to be verified by pump testing after the well is installed. The cost estimate contains sufficient contingency to allow installation of up to three pumping wells if the pump tests indicate additional wells are required.

2. Based on our calculation using both the Keely-Tsang equation (1983) and the method proposed by Grubb (1993), we predict that approximately 230,000 gpd, or 160 gpm of withdrawal would be required to maintain an inward gradient for the industrial site.

3. Based on the disposal unit rates quoted by the Granite City POTW, and assuming that the pumping rate is approximately 160 gpm, or 230,000 gpd, the annual cost for disposal are estimated to be approximately $76,000.

4. Based on the contaminant limits for total lead of 0.5 mg/L quoted in the Granite City Sewer Use Ordinance (No. 3819), and on the results of several years of groundwater sampling data (average total lead concentration of 0.099 mg/L), it does not appear that the disposal of the groundwater produced from the NL/Taracorp site will add enough contaminants to require a reclassification of the sludge produced by the wastewater treatment plant.

5. The cost estimates quoted for the FS were based on the best available information. WCC personnel discussed a variety of scenarios with drilling contractors, remediation contractors, equipment manufacturers, the local POTW, and experienced environmental professionals within the WCC organization.

The effect of inflation and future cost increases is evaluated in Table 4-4 of the FS Addendum. Present worth costs over the projected 30 year life of the project are evaluated for discount rates of 3%, 5%, and 10%.

6. U.S. EPA did not ignore the previous work of IEPA. IEPA studies, along with other historical information, was reviewed when setting up the Remedial Investigation for the NL Site. U.S. EPA collected further ground water samples, as suggested in IEPA reports; however, due to the standard procedure (in 1987) of filtering metals samples with a .45 micron filter prior to sample analysis, the lead contamination problems in ground

said comments, that are summarized below:

1. U.S. EPA has overestimated the true metals concentrations in the ground water by only considering the analytical results of unfiltered ground water samples. The more appropriate ground water sampling methodology for metals is either filtering samples or collecting samples with low flow techniques.

2. Geraghty & Miller's reinterpretation of the data, which excluded the unfiltered samples unless sampled by low flow techniques, indicates that the average metals concentrations are below the Maximum Containment Levels ("MCLs"), except for cadmium, and below the Illinois Groundwater Quality Standards ("IGQSs"), except for cadmium and lead. However, the average concentrations of cadmium and lead exceeded the MCLs and IGQSs only because high concentrations in a few wells skewed the averages higher. When these wells are excluded, the average cadmium concentrations actually fall below the MCLs and IGQSs, and the average lead concentrations fall below the MCLs and are only 1.3 times the IGQSs.

3. The remedy proposed by U.S. EPA is unwarranted because the ground water does not pose a risk to human health. The ground water is not used for potable purposes at or around the Site. As a result, there is no exposure pathway and no risk to the citizens of Granite City.

4. Most importantly, U.S. EPA's proposed ground water pumping remedy simply would not work. The elevated metals concentrations in the samples collected by U.S. EPA were due to high turbidity in the samples. In other words, the metals concentrations in the samples were caused by metals in the sediments, not be metals dissolved in the ground water. When ground water recovery wells are installed as part of a ground water pumping system, they must be designed to minimize the sediments in the extracted ground water to avoid damage to pumps and other equipment. Thus, the extracted ground water would at most contain low levels of metals while the vast majority of the metals would remain tied to the sediments and would be immobile and unrecoverable.

5. Even if elevated levels of metals did exist in the ground water at the Site, which does not appear to be the case, a remedy based on capping the source area to reduce infiltration, natural attenuation and monitoring would provide the same protection to human health and the environment as U.S. EPA's proposed remedy and would be much less costly.

uncover some drinking water uses of ground water downgradient from the NL Site. Containment is marginally more expensive than attenuation only, but U.S. EPA feels that the additional expense is justified in light of the above health and environmental considerations.

Attachment 4

STATISTICAL ANALYSES OF DATA FROM THE MADISON COUNTY LEAD STUDY AND IMPLICATIONS FOR REMEDIATION OF LEAD-CONTAMINATED SOIL

Allan H. Marcus, PhD

Environmental Criteria and Assessment Office
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Attachment 4

STATISTICAL ANALYSES OF DATA FROM THE MADISON COUNTY LEAD STUDY AND IMPLICATIONS FOR REMEDIATION OF LEAD-CONTAMINATED SOIL

Allan H. Marcus, PhD

Environmental Criteria and Assessment Office
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

TABLE OF CONTENTS

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The purpose of this report is to provide an independent interpretation of the data and reports generated as part of an epidemiologic study of childhood lead exposure in the Madison County, Illinois conducted in 1991.

Children and pregnant women are the human subpopulations most susceptible to the effects of lead. Identification of the major sources of environmental lead exposure for children with elevated blood lead concentrations became the primary focus of the epidemiologic study of childhood lead exposure in the Madison County, Illinois study[1] conducted in 1991 as directed by the Agency for Toxic Substances and Disease Registry (ATSDR). (While the study was directed by the ATSDR, it was primarily carried out by the Illinois Department of Public Health (IDPH) through its contractor, Institute for Evaluating Health Risks (IEHR), as is discussed more specifically below [2]).

Childhood blood lead depends on many factors. The most important factors must necessarily be related to some environmental sources of lead, since lead is not created in the child's body, but must be brought into the body by exposure to lead occurring outside of the body. Typically, lead is carried in some medium of exposure. The ingestion media most usually encountered by children include food, drinking water, and non-food media such as soil, household dust, and chips or flakes of

---

[1]While the identification of the major sources of environmental lead exposure for children with elevated blood lead concentrations became the primary focus of the epidemiologic study of childhood lead exposure in the Madison County study by the authors of the report describing the study (IDPH/IEHR 1994), this purpose was not clearly articulated by ATSDR when the study began. (For example, one of the stated purposes of the study was to determine the level of environmental lead and cadmium found in target areas and compare them with levels of contamination observed in comparable non-target areas.) Therefore, the study methodologies were not suitably designed to be able to make firm conclusions about the major sources of environmental lead exposure for children or to provide an adequate basis for comparison with many other studies of blood lead and environmental lead. Even given these shortcomings, the data available from the blood study can be analyzed and lend support to retaining the 500 ppm residential soil lead cleanup level.

[2]U.S. EPA participated by providing contractor assistance as guided by IDPH and ATSDR.

lead-based paint. Most lead experts agree that household dust is a very important medium for childhood lead exposure, and is likely the primary exposure pathway for lead in soil and for lead in interior lead-based paint. Also, ingestion of exterior dust from soil is a direct exposure pathway to soil lead that may be nearly as important as the indirect pathway from soil through household dust. All of the lead in the child's body has come from current or historic intake from these media, from other media such as inhalation of airborne particles, or from exposure in utero to lead in the mother's blood.

Many other factors may modify the blood lead concentration in a child who is exposed to environmental lead. The most important modifiers affect the amount of lead consumed in different media, such as the amount of fine soil and dust particles that the child eats during normal play activity. Some of the modifying factors for lead intake (See Section 3.1 of this report) can sometimes be estimated, but in epidemiology studies such as that carried out in Madison County, the modifying factors are only inferred from family characteristics such as parental education or income, from ethnicity or race, or from other child characteristics such as age or sex. The Madison County study collected data on a large number of potential modifying factors, but it is important to remember that the modifying factors must necessarily have a secondary role compared to the measurable components of lead in the child's environment.

The study was directed by the ATSDR in 1991 and carried out by the IDPH, primarily via its contractor, IEHR, and U.S. EPA (as guided by IDPH and ATSDR). Analyses of the data were presented in a draft report by IEHR and IDPH (February 1994), hereafter described as the IEHR/IDPH report, and by ATSDR in a separate report (May 1994) with a more cursory analysis. U.S. EPA provided a critical review of these analyses (Marcus et al., May 1994), but it did not provide an analysis of the data since it did not yet have access to the data. The preliminary report of the reexamination of these data (Marcus 1994) was submitted as part of the Administrative Record Update as part of U.S. EPA's proposed plan and public comment period for the residential soil cleanup level in October, 1994. U.S. EPA requested access to the data from IDPH (through a request by the U.S. Department of Justice). Data on blood lead, environmental lead, and family interviews for 490 children in Madison County, Illinois, were provided to U.S. EPA by the IEHR, IDPH's contractor, in late 1994. The data were sent to U.S. EPA on diskette in ASCII format. U.S. EPA converted these data into a SYSTAT (Wilkinson 1992) data file used in analyses reported here were performed. Additional analyses required creation of SAS (SAS 1990) data sets. The data set was incomplete in some important ways, as described below.

In this report, U.S. EPA performs reanalyses of the data. The purposes of the for U.S. EPA's reanalyses are:

1. To assess the results described in the IEHR/IDPH report (1994) for use in evaluating childhood lead exposure in Madison County;
2. To extend these analyses so as to obtain relevant site-specific inferences about environmental pathways for childhood lead exposure for Madison County children, with particular emphasis on those locations nearest the former NL/Taracorp Lead smelter at the NL/Taracorp Superfund Site;
3. To provide site-specific information about relevant parameters in the EPA Integrated Exposure, Uptake, and Biokinetic Model for Lead (IEUBK Model) which was used by U.S. EPA in certain risk evaluations of child blood lead risk;
4. To evaluate U.S. EPA's proposed soil remediation level of 500 ppm using this recent information.

The IEHR/IDPH report evaluates some of the relationships among child blood lead, environmental lead, other environmental factors affecting blood lead, sociodemographic factors, and individual child-specific behavioral factors. Many of the relationships are characterized by bivariate correlation coefficients, or by related quantities such as the multiple correlation coefficient for the multiple regression analyses (the only multivariate procedure considered in the IEHR/IDPH analyses). The analyses in the IEHR/IDPH report provides an inadequate description of child lead exposure in Madison County. As shown herein, the analyses are so incomplete as to give a misleading impression of childhood lead exposure. U.S. EPA's analyses will provide a more balanced view of child lead exposure in Madison County, clarifying the important but distinctly different roles of lead in soil, in deteriorating lead-based paint, and in household dust, with emphasis on resolving issues that may affect decisions about remediation of lead sources near the NL/Taracorp lead smelter and elsewhere in Madison County. U.S. EPA has established the following:

1. There are some areas in the Madison County study that clearly show an excessive number of cases of children with elevated blood lead concentrations. The number of cases is elevated by comparison with other parts of Madison County, and elevated by comparison with current EPA guidelines. These cases are concentrated near the NL/Taracorp lead smelter and in a few more remote locations. These suggest localized, site-specific sources of lead exposure.

2. There are some serious inadequacies in the design of the study that complicate the analysis and interpretation of the data, particularly with the possibility of confounding of some environmental and demographic factors. However, the potential problems are not so serious as to prevent far more detailed and complete conclusions than were reached in the IEHR/IDPH report.

3. The IEHR/IDPH report failed to consider certain non-standard features of the soil sampling and dust sampling and reporting protocols that complicate the use of these data for inferences about environmental lead sources. In particular, the reported dust lead concentrations used for analyses in the Madison County study were mathematical averages of fine dust particles (which can be picked up on the child's hands and

ingested), and large particles including lead paint chips that are much less likely to be ingested during normal hand-mouth activity. This differs from dust lead measurements used in most earlier studies, and is likely to bias the estimated effects of dust and paint on blood lead. U.S. EPA's analyses suggest that most dust lead concentrations above 1000 ppm reported in the Madison County Study are likely to be biased above the values that would have been obtained using only fine dust particles, thereby overstating the role of lead paint on dust lead and on blood lead.

4. Average soil lead concentration is nearly inversely proportional to distance from the NL/Taracorp lead smelter (See Figure 5), with a few isolated locations far from the previous active NL/Taracorp lead smelter that also have high soil lead. Many of these spots are believed to be in Eagle Park Acres or in Venice Township, where waste pile material containing lead battery casing chips was used as fill or for repairing city streets and alleys. Exterior lead paint played a much smaller role in soil lead concentrations than did distance from the NL/Taracorp lead smelter.

5. Most of the lead in house dust near the NL/Taracorp lead smelter is likely to have come from lead in soil. In most homes near the smelter, soil lead is more likely to be the major source of lead in house dust than lead in interior paint. Interior lead-based paint is likely to be a more important source of lead in house dust than is soil lead only in some homes at a great distance from the NL/Taracorp lead smelter (ring 7 or at least 3/4 mile) where there are no other known sources of lead.

6. Dust lead inside the house depends mainly on soil lead from the yard and on deteriorating lead paint inside the house, modified somewhat by overall building condition. The effects of soil lead and lead paint on blood lead are therefore primarily indirect effects, in which these lead sources contribute lead to house dust, a medium that is more accessible to the child.

7. The hierarchical regression method used in the IEHR/IDPH

report to identify significant lead sources was seriously biased. A more appropriate application of the hierarchical regression method in Section 4 herein shows that lead in soil is a more significant predictor of elevated blood lead than is lead paint, but that inclusion of dust lead loading in the model can explain about as much of the variance in blood lead as all of the modifying factors combined. Soil lead is not strongly confounded with other significant predictors of dust lead loading, including building condition, age, race, parental education and income, child's outdoor play, lead in drinking water, and recent refinishing or remodelling. This allows estimation of both the direct effect of soil lead on blood lead, and the indirect effect of soil lead through the dust lead pathway. While the most important predictors of blood lead were dust lead loading and child age, soil lead had a smaller statistically significant effect on blood lead over and above the effect of dust lead.

The overall effect of soil lead on blood is very clear, as shown in Tables E-1 and E-2. Table E-1 shows the percentage of children in the Madison County Lead Study who had blood lead concentrations of 10 ug/dl or greater, which is a level of concern for increased potential of health risks. The level of concern is defined by blood lead levels at which most individuals in a population of children are not expected to have health effects of major consequence. The level of concern is not a threshold level below which all individual children are free of lead-induced health effects. The blood lead level of concern expresses scientific judgements about health effects of lead exposure in a form that is useful in evaluating public health implications of various actual or hypothetical levels of lead exposure, and is not meant to imply the biological effects do not occur at lower levels of exposure.

The percentage of children with elevated blood lead levels whose yard soil lead concentration is less than 250 ppm is only 6 percent (i.e., 10/162 children). The percentage is much larger for children with residential soil lead concentrations of 250 to

499 ppm (20% or 33/169 children); 500 to 999 ppm (21/104 children or 20%); and 1000 ppm or greater (12/39 children or 31 percent).

8. African American children in the Madison County Study have on average about 1.2 ug/dl higher blood lead than other children of the same age, everything else being equal. It is possible that race/ethnicity represents a surrogate measure for locations south and southwest of the NL/Taracorp lead smelter, or some other unknown covariates.

9. Soil lead is a significant predictor of blood lead in any appropriate linear or additive model specification, which is biologically and physically more realistic than the log-log model in the IEHR/IDPH report.

TABLE E-1. Percentage of Children with Blood Lead of 10 ug/dl or Greater in Madison County Lead Study

Soil Lead (ppm)	Number of Children	Percent
0 - 249	10/162	6
250 - 499	33/169	20
500 - 999	21/104	20
1000 +	12/39	31
Unknown	2/16	-
Total	78/490	16

Blood lead concentrations of 20 ug/dl or greater are sufficiently high to warrant individual immediate intervention. These also show a very clear relationship to soil lead, with a marked increase at soil lead concentrations of 500 ppm or greater (6.7 to 7.7 %), compared to only 1.9 % of children living on yards with soil lead less than 250 ppm.

TABLE E-2. Percentage of Children with Blood Lead of 20 ug/dl or Greater in Madison County Lead Study

Soil Lead (ppm)	Number of Children	Percent
0 - 249	3/162	1.9
250 - 499	5/169	3.0
500 - 999	7/104	6.7
1000 +	3/39	7.7
Unknown	0/16	-
Total	18/490	3.7

10. Visual observation and analyses of Madison County data show the following:

(A) Significant transport of lead from soil to household dust;

(B) Bare areas on soil in many yards, and significant amount of child outdoor play activity, especially in neighborhoods closest to the NL/Taracorp smelter;

(C) Quantitative relationship of soil lead with the NL/Taracorp smelter, implying that soil derived from historical deposition of airborne particles from the secondary lead smelter and related smelter wastes are likely to have bioavailability and other properties similar to particles derived from smelter air emissions in other communities; and,

(D) Quantitative strong relationship of blood lead to lead in household dust, and indirectly to lead in soil through the soil-to-dust-to-child pathway.

11. Lead particles emitted from smelters often have high concentrations of relatively soluble species, such as lead oxides and lead sulfates. Lead in soil and house dust derived from smelter emissions are therefore more likely to consist of small particles of relatively bioavailable species of lead. Since the analyses in this report point strongly towards the NL/Taracorp smelter as the source of most of the lead in soil and house dust in most of the housing located in the rings closest to the smelter, the lead particles encountered by children residing there are likely to be highly bioavailable, and the standard assumptions about bioavailability used in the IEUBK model are consistent with site-specific observations and analyses. 11. Site-specific conditions at the NL/Taracorp lead site are therefore very close to those found at sites for which the IEUBK model was calibrated and for which the default parameters are appropriate.

12. When data from the Madison County Lead Study were used

as a basis for evaluating the predictiveness of the IEUBK model, systematic deviations were noted when the reported dust lead concentrations were used as input variables. These deviations were largely eliminated when dust lead concentration was estimated using the IEUBK model default method, dust lead concentration = 0.7 soil lead concentration + 10 ppm. This is consistent with the results of the regression models and the environmental pathway models, which found some indication that dust lead concentrations above about 1000 ppm may be inflated by inclusion of large paint chips on the floors or window sills that are probably not accessible to the child.

13. Using default input parameters in the IEUBK model, and allowing for differences in the soil lead contribution to dust lead within the range of values estimated at various parts of the site, target levels for soil remediation are in the range of 350 to 480 ppm. Inclusion of lead paint lowers these levels substantially (i.e., 115 to 350 ppm).

ASSESSMENT OF DATA FROM THE MADISON COUNTY LEAD STUDY AND IMPLICATIONS FOR REMEDIATION OF LEAD-CONTAMINATED SOIL

1 INTRODUCTION

Children and pregnant women are the human subpopulations most susceptible to the effects of lead. Childhood blood lead levels depend on many factors. The most important factors must necessarily be related to some environmental sources of lead, since lead is not created in the child's body, but must be brought into the body by exposure to lead occurring outside of the body.

Typically, lead is carried in some medium of exposure. The ingestion media most usually encountered by children include food, drinking water, and non-food media such as soil, household dust, and chips or flakes of lead-based paint. Lead inhaled from the air used to be an important exposure medium, but with the phaseout of leaded gasoline in the 1970's and 1980's, inhaling of lead in air is now a relatively minor pathway of exposure unless the child lives near active primary or secondary smelters or lead battery processing plants, or some similar specific sources. Rare cases of lead poisoning from other sources, such as certain ethnic medicines, foods, or cosmetics, may also occur. Finally, lead is readily transferred during pregnancy from the mother to the fetus, and after birth may be transferred from the nursing mother to her infant through the mother's milk, so that some part of the mother's environmental lead exposure is transferred to the newborn child. Thus, all of the lead in the child's body has come from someplace outside. Identification of the major sources of environmental lead exposure for children with elevated blood lead concentrations is the primary challenge in the epidemiologic study of childhood lead exposure in the Madison County study.

Many other factors may modify the blood lead concentration in a child who is exposed to environmental lead. The most important modifiers affect the amount of lead consumed in different media. For example, some children may consume a great deal of tap water early in the day, either as drinking water or as water used to make up the child's formula; other children, in other households, may drink much less tap water, so that the concentration of lead in the tap water is not the only factor that affects the amount of lead taken in by the child from tap water, and two children exposed to exactly the same concentration of lead in their drinking water may have different concentrations of blood lead attributable to tap water.

The situation encountered in the Madison County study is that children may be exposed to elevated levels of lead in several media encountered in their homes, including lead in household dust, in yard soil, and in lead-painted walls and trim inside and outside the house. The amount of time that the one child spends playing in the yard outside the house, on the floor, or at some other non-home location can differ greatly from the activity pattern of another child, and the amount of surface soil or dust that the child picks up on his or her hands and transfers to the mouth during normal play activity also depends on parental awareness, hygiene habits and other factors. However, even if the child consumes large quantities of media such as water, dust, soil, or paint, there is no lead exposure unless there is lead in the media.

Some of the modifying factors for lead intake (See Section 3.1 of this report) can sometimes be observed, but in many epidemiology studies such as that carried out in Madison County, the modifying factors are only inferred from family characteristics such as parental education or income, from ethnicity or race, or from other child characteristics such as age or sex. The Madison County study collected data on a large number of potential modifying factors, but it is important to remember that the modifying factors must necessarily have a secondary role compared to the measurable components of lead exposure.

The study was directed by the ATSDR in 1991 and carried out by the IDPH, primarily via its contractor, IEHR, and U.S. EPA (as guided by IDPH and ATSDR). Analyses of the data were presented in a draft report by IEHR and IDPH (February 1994), hereafter described as the IEHR/IDPH report, and by ATSDR in a separate report (May 1994) with a more cursory analysis. U.S. EPA provided a critical review of these analyses (Marcus et al., May 1994), but it did not provide an analysis of the data since it did not yet have access to the data. The preliminary report of the reexamination of these data (Marcus 1994) was submitted as part of the Administrative Record Update as part of U.S. EPA's proposed plan and public comment period for the residential soil cleanup level in October, 1994. U.S. EPA requested access to the data from IDPH (through a request by the U.S. Department of Justice). Data on blood lead, environmental lead, and family interviews for 490 children in Madison County, Illinois, were provided to U.S. EPA by the IEHR, IDPH's contractor, in late 1994. The data were sent to U.S. EPA on diskette in ASCII format. U.S. EPA converted these data into a SYSTAT (Wilkinson 1992) data file used in analyses reported here were performed. Additional analyses required creation of SAS (SAS 1990) data sets. The data set was incomplete in some important ways, as described below. In this report, U.S. EPA performs reanalyses of the data. The purposes of the for U.S. EPA's reanalyses are:

1. To assess the results described in the IEHR/IDPH report (1994) for use in evaluating childhood lead exposure in Madison County;

2. To extend these analyses so as to obtain relevant site-specific inferences about environmental pathways for childhood lead exposure for Madison County children, with particular emphasis on those locations nearest the NL/Taracorp smelter;

3. To provide site-specific information about relevant parameters in the EPA Integrated Exposure, Uptake, and Biokinetic Model for Lead (IEUBK Model) which predicts the

distribution of blood lead concentrations expected in children of a specific age who all have the same specific set of environmental lead exposure concentrations—equivalently, the risk of incurring different blood lead concentrations for any child with such exposure;

4. To evaluate U.S. EPA's proposed soil remediation level of 500 ppm using this recent information.

This report provides the technical basis for the inferences made in U.S. EPA's preliminary report of results. The U.S. Environmental Protection Agency will describe the methods used in the analyses, a complete set of results, and the basis for U.S. EPA's conclusions. This report is divided into the following sections. Section 2 provides a detailed narrative for the simple graphical and tabular presentations given in the preliminary report (U.S. Environmental Protection Agency, October, 1994). Section 3 evaluates potential problems of confounding, and describes several approaches to assess the extent of confounding in the Madison County study and to alleviate the problem where it exists. In particular, the role of hierarchical regression modelling is discussed.

Section 4 describes the results of several approaches to deriving statistical relationships among child blood lead and a host of demographic, behavioral, and environmental factors that may contribute to blood lead. The regression modelling approaches in Section 4 also help to identify important variables for subsequent analyses. One approach parallels the log-log regression methods used in the IEHR/IDPH report, but enlarges the approach to a wider range of possible factors contributing to child blood lead. The second approach is similar to earlier EPA analyses and is useful in evaluating exposure pathways assumed in the IEUBK model.

During the course of these analyses, it became obvious that several extremely high dust lead concentrations had an undue influence on the nature of the regression analyses. Subsequent investigation showed that many of the dust lead concentrations reported in the study consisted of mathematical averages of dust lead concentrations in fine particles and dust lead concentrations in larger debris, including lead paint chips that may have seriously biased the reported concentrations. Consequently, it was necessary to perform subsequent analyses with and without these extremely high dust lead values in order to evaluate the sensitivity of the results to inclusion of data that differed substantially from data used in other studies. The regression models also provide a basis for assessing the relative importance of exterior lead-based paint and distance from the NL/Taracorp smelter as contributing sources of lead in soil, and the relative importance of soil lead, interior lead-based paint, and exterior building condition as contributing sources of lead in household dust.

Section 5 reports the results of analyses in which an explicit causal model is assumed for environmental lead pathways, particularly from paint to soil and house dust. These results are also described graphically and in tables, with a minimum of technical details. The technical details are given in Appendix B. The use of the analyses in providing input to the IEUBK model is described in Section 6. Section 7 evaluates the adequacy of the IEUBK model for estimating blood levels for children in the Madison County blood study. Sections 6 and 7 present the basis for a soil lead cleanup level. Section 8 describes the soil lead results when input values for the IEUBK Model from Section 3.1 are used, and describes the reevaluation of the soil lead cleanup level for the NL/Taracorp Superfund Site.

The main body of the text of this report describes the results of the analyses with little technical detail. Some readers may wish to review these technical details, so that a much more extensive mathematical presentation of the results is given in the Technical Appendices.

2 DESCRIPTIVE STATISTICAL ANALYSES

2.1 Simple Statistical Summaries

The U.S. Environmental Protection Agency's analyses are all related to assessing the risk of elevated blood lead that exposure to lead from diverse sources poses to children in Madison County, with particular attention to the former NL/Taracorp lead smelter at the NL/Taracorp Superfund Site in Granite City, Illinois and environs. It is generally recognized that there are other potential sources of lead in Madison County to which children may be exposed, such as waste pile material used for street repairing in Venice, battery casings and waste pile material used as fill in Eagle Park Acres, and deteriorating lead-based paint on older housing throughout the community. In all of these, there is an important component of location relative to the NL/Taracorp lead smelter. The data provided to U.S. EPA only contain a single spatial component, rings of so-called "DISTANCE", which is the approximate distance of the household from the NL/Taracorp smelter or center of the site, in units of about 1/8 mile. This is shown in Map 1. The U.S. Environmental Protection Agency has therefore reported the mean or geometric mean values of the variables in the data set in each ring. The number of children with blood leads (NC) and number of households (NH) with children is also reported. Each of the other variables is either a household or family measurement (coded H) or an individual child measurement (denoted C). The uncertainty associated with each mean is either the standard error (denoted s.e.) or percentage relative standard error (denoted r.s.e.). These are shown in Table 1 through Table 5, and graphically in Figure 1 through Figure 18. Standard errors are shown with each mean or percentage, and relative or geometric standard errors with each mean geometric mean in these figures.

2.2 Blood Lead

Table 1 shows that the percentage of children with elevated blood lead concentration, defined as blood lead of 10 ug/dl or greater, tends to decrease with increasing distance from the NL/Taracorp smelter. There are small deviations from this rule, consistent with random deviations expected in small to moderate sized groups of children, except for distance ring 9, where 5 of 22 children have blood leads of 10 ug/dl or higher. This small deviation may correspond to exposure to other sources of lead, such as battery casing debris, in remote neighborhoods in Venice Township or in Eagle Park Acres or other unincorporated parts of Madison County. The percentage of children whose blood lead concentrations are 15 ug/dl or greater are particularly concentrated near the NL smelter, at rings 1, 2, and 3 on Map 1. The percentage of children with blood lead concentrations of at least 20 ug/dl are also concentrated in rings 2 and 3, lower in rings 4, 5, and 6. In view of the small number of children in ring 1, it is not surprising that no child with blood lead at least 20 ug/dl is found in ring 1 (n is approximately 9). This is shown in Figures 1, 2, and 3 respectively. Figure 4 and Table 1 show that the geometric mean blood lead concentration decreases with increasing distance from the NL/Taracorp smelter, in general. Some figures (such as Figures 19-21) are plotted on a natural logarithm scale (base e, not base 10), since the distribution of blood lead concentration and most other variables used in U.S. EPA analyses are not normally distributed, but have a substantial amount of skewness towards high values.

2.3 Environmental Lead

2.3.1 Lead in Residential Soil and in House Dust

Environmental lead concentrations also show a striking relationship with distance, as shown in Table 2 and in Figures 5 through 7. Soil lead concentration shows a very consistent decrease with increasing distance from the NL/Taracorp smelter, except for 2 households in ring 10. The reader should note that the standard errors are relatively small, compared to those in most other indices, showing that the relationship between soil lead and distance is relatively well defined. Table 2 and Figure 6 show a very similar relationship between distance and dust lead concentration, again excepting ring 10. Table 2 and Figure 7 also show a very similar relationship between distance and dust lead loading, with larger variability than dust lead concentration, but with greater consistency including ring 10. Mean blood lead concentration, soil lead concentration, house dust lead concentration, and house dust lead loading show very similar patterns of decreasing concentration with increasing distance from the NL /Taracorp lead smelter, on average.

2.3.2 Lead-Based Paint

Other environmental indices are not shown in the Tables, but in Figures 8 through 11. Loadings of deteriorating lead paint inside and outside the house show little or no relationship to distance from the NL /Taracorp. This suggests that deteriorating lead-based paint is not the most important direct environmental factor in childhood blood lead in Madison County, and is much less important than soil lead and dust lead. This is not to say that paint lead may not be a significant indirect source of childhood lead exposure. Deteriorating interior lead-based paint may be a significant contributor to household dust along with lead in soil. Deteriorating exterior lead-based paint may be a significant contributor to lead in soil along with proximity to the smelter but the soil lead measurements in the Madison County Study found only a slight contribution of exterior lead paint to lead in soil away from the dripline. This will be shown in subsequent analyses. Figure 8 shows that the interior lead paint hazard index has only a weak relationship to distance from the NL/Taracorp smelter. This interior lead paint cannot explain all of the blood lead variability in the data set. Lead paint hazard index was measured in the data set by the product of the paint condition (from 0 to 10 on a scale of increasing deterioration) times the lead paint loading measured by X-ray fluorescence (XRF) analyzer. Figure 9 shows that exterior lead paint hazard has even less average relationship to distance. There is in fact a strong relationship between environmental lead and lead-based paint, but this is visible after the dominant effect of distance from the NL/Taracorp smelter is removed, using more sophisticated statistical methods.

2.3.3 Lead in Drinking Water

Figure 10 shows that the household tap water lead concentration is highest in the housing closest to the NL/Taracorp smelter, but otherwise show little relationship to distance. Thus, lead in tap water may be a contributing source of child blood lead and is, in some analyses, but is not the primary factor.

2.4 Modifying Factors for Lead Exposure: Household Environment, Demographics, and Individual Child Behavior

The relationship between blood lead and environmental lead is affected by demographic and behavioral variables. While a child could not acquire an elevated blood lead concentration without ingesting or inhaling environmental lead from some medium, contact with and exposure to that medium, and the amount of intake from the medium depend strongly on social and behavioral aspects of the environment. Most of the variability in child blood lead concentrations can be attributed to inter-individual differences in lead exposure, absorption, and biokinetics. For example, poor nutrition may cause an increase in lead absorption, or possibly even an increase in lead intake. Even in the same environment, some children will ingest little lead from soil or dust, or will absorb little of what they ingest, while others will ingest and absorb a much larger quantity. This does not mean that the amount of lead in the environment is unimportant, since almost all studies have found a strong relationship between some components of environmental lead and blood lead in children. It does mean that the modifying effects of socio-demographic conditions that affect exposure, individual behaviors, and individual absorption and biokinetic elimination of lead must be included in a mathematical model in order to interpret the data.

2.5 Household Environment

2.5.1 Dust in the Household

Total dust loading shows almost no relationship to distance from the NL/Taracorp smelter, on average, so that increased dustiness of homes cannot explain the higher household dust lead loadings found near the NL/Taracorp smelter. As will be shown later, total dust loading is an extremely important predictor of dust lead loading, but it is the higher concentration of lead in household dust or soil that accounts for higher dust lead loadings near the NL/Taracorp lead smelter. Figure 11 shows somewhat higher dust loadings in rings 2 and 10, although there is a great deal of uncertainty associated with the geometric means from such a small number of households.

The reader should note at this point that there is an exact mathematical relationship between dust lead concentration, dust lead loading, and dust loading. Dust lead concentration is measured in micrograms of lead per gram of dust. Dust lead loading is measured in micrograms of lead per square meter of surface. Total dust loading is measured in units of milligrams of dust per square meter of surface. Thus, in the IDPH data set,

(Dust lead concentration) * (Dust loading) / (Dust lead loading) = 1000.

This implies an exact linear relationship when logarithms are taken on both sides of this equation. The terms "log" or "ln" are used interchangeably in this report to mean the natural or base (e) logarithm. The above equation is equivalent to:

- log(Dust lead concentration) + log(Dust loading) - log(Dust lead loading) = log(1000)

This is useful in providing a benchmark for the reader to interpret the concept of 'collinearity' discussed below. Household dust loading is correlated with many other socio-demographic variables, but plays a very important role in household environmental lead exposure.

2.5.2 Housing Age

Table 3 shows some of the demographic characteristics that U.S. EPA has found useful in interpreting the Madison County lead study. There is a clear gradient from older housing near the NL/Taracorp smelter to newer housing farther away. U.S. EPA has assigned the midpoint of each decade in order to calculate a mean as shown in Table 3, and a nominal value of 1905 to all pre-1910 housing. Housing age is clearly a surrogate for historical exposure to smelter emissions and soil deposition, for increased likelihood of encountering lead-based solder in plumbing materials or lead alloy pipes and fixtures. Older houses are also much more likely to have deteriorating lead-based paint. U.S. EPA did not use housing age in subsequent analyses because it was unknown for over 30% of the households in the study.

2.5.3 Condition of the Building Exterior

Condition of the building also turned out to be a useful predictor, both for blood lead (as a socio-demographic surrogate) and for environmental lead. This was coded 1 for least deteriorated buildings, 3 for very deteriorated buildings, and 2 for moderately deteriorated buildings. Subsequent analyses showed that building condition was about as predictive treated as a metric or numeric variable as it was when coded into three classes, so that the mean building condition is shown in Table 3 and in Figure 12, and shows a steady improvement in building condition from ring 2 outward. This variable was used in many analyses, even though it was missing for about 20 percent of all households in the study, and is denoted BLDGCOND in some of U.S. EPA's tables. Missing values were imputed in the IEHR/IDPH report using the overall mean building condition value of 1.389;

this variable is denoted BLDCONIM in some of U.S. EPA's tables. Since building condition shows a good relationship with distance, U.S. EPA also tested a scheme in which missing values where imputed by using the average value for the ring shown in Table 3, for example assigning 2.00 to missing values of building condition for ring 2, 1.63 for ring 3, 1.50 for ring 4 and so on. This scheme proved to be much more predictive than using the grand mean of 1.389, and is denoted BLDGCIMP.

2.5.4 Use of Home Air Conditioners

Air conditioning is both an indicator of economic status and a physical device that may reduce the amount of airborne dust particles and resuspended exterior dust from surface soil entering the house through the windows and doors. However, the pattern with distance shown in Table 3 is not exactly parallel to that of other variables. Although selected in other analyses, this variable did not prove as highly predictive of child blood lead as was suggested in earlier analyses.

2.6 Demographic Factors

2.6.1 Parental Education

Parental education is often the most significant component of indicators of socio-economic status (denoted SES in other studies). This was characterized numerically by the number of years of education completed. Some coding conventions were necessary, such as 12 years for completion of a GED, 13 or 14 years for attendance at technical schools or junior colleges, and 17 years as a nominal value for any graduate or professional schools. U.S. EPA found that parental education could predict blood lead better if the parents' actual educational level was specified and used as a predictor rather than simple dichotomies such as coding "less than high school" vs. "high school graduate or above". Table 3 and Figure 13 show that mean number of years increases steadily with increasing distance from the NL/Taracorp smelter, from a minimum at ring 2. In later analyses, parental education was a good predictor of childhood blood lead levels. It is important to note that the correlation between education and dust lead was not strongly correlated, and that education was an important covariate of blood lead, but not a strong confounder for environmental lead in dust or soil.

2.6.2 Parental/household Income

Household income was reported in inexact groups, intervals of $5,000, in order to improve the confidentiality of the study. U.S. EPA used the midpoint of each interval as a numeric covariate, for example, $2500 for the group reporting 0 to $5000 per year. Even though parental education was much more predictive as a sociodemographic factor, the logarithm of household income was an additional statistically significant predictor of blood lead. The incidence of children with elevated blood lead was lower in higher income households even after statistical adjustment for environmental lead indicators, suggesting that the effect of environmental lead was not completely confounded with socioeconomic factors.

2.6.3 Home Ownership

Home ownership shows a clear increase with increasing distance from ring 2 outward, as shown in Table 3 and Figure 14. This variable also proved less predictive than other socio-demographic variables, but was included in preliminary assessments.

2.6.4 Race and Ethnicity

Race and ethnicity are among the most important demographic variables in this data set. Many other studies have found higher blood lead concentrations in children from certain racial or ethnic sub-populations, even when adjusted for similar levels of environmental lead and other socio-demographic variables (Stark et al. 1982; Weitzmann et al. 1993). This study coded racial sub-groups as 1 = White, 2 = African American, 3 = Asian or

Pacific islander, 4 = American Indian or Alaska native (Q. 205). Because of the small number of children in categories 3 or 4, these were sometimes combined with category 2 = African American into a new "Non-white" group. In other analyses, another variable was created by coding category 2 as 1, and combining categories 1, 3, and 4 and coded them as 0. Interview questions also identified Hispanic ethnicity (Q. 206) but these data were not provided to us. As shown in Table 3 and Figure 15, non-white households are located differentially from ring 6 outward to ring 9. U.S. EPA suspects that the majority of these are located in the communities of Madison and Venice, but no data were provided to U.S. EPA that would allow confirmation of the community in which the non-white households were located. Additional analyses for these more highly impacted subgroups may be useful.

The IEHR/IDPH report has found no apparent difference in race/ethnicity relative to childhood blood lead levels. However, a more detailed statistical analysis carried out by U.S. EPA shows that race/ethnicity does appear to have a significant effect in childhood blood lead levels in Madison County. The analyses in the IEHR/IDPH report may have obscured this finding, since simple comparisons of blood lead concentrations among white and non-white residents of Madison County ignore the fact that the majority of non-white residents lived at distances at which there were typically lower soil and dust lead concentrations.

2.6.5 Number of Pre-School Children in the Household

Some previous studies have suggested that households with multiple pre-school age children may allow greater childhood lead exposure, resulting in elevated blood lead concentrations (Stark et al. 1982). Table 3 and Figure 16 show that there is some tendency towards larger numbers of children in households closer to the NL/Taracorp smelter, but the tendency is not striking and proved to be less predictive than other socio-demographic covariates. However, from the point of view of community risk assessment, it is important to note that households with several pre-school children may be differentially located in certain areas of the community. In some inner-city neighborhoods in the Urban Soil Lead Abatement Demonstration Projects in Baltimore, Boston, and Cincinnati, larger houses and larger apartments in old housing were preferred by families with multiple children. In view of the rapid turnover of rental housing in these communities, the number of lead-exposed children over some period of time may be larger than can be estimated from a simple cross-sectional study such as the Madison County study.

2.6.6 Cigarette Smoking

One of the household characteristics studied in detail was the number of cigarettes smoked per day by the adult who was interviewed (questionnaire item 409, especially Q. 409.3). While some household dust lead may come from cigarette smoke particles, it is also possible that cigarette smoking is a surrogate for other family characteristics that affect childhood exposure to dust and soil. Further study of this relationship would be interesting. Table 3 clearly shows a gradient of smoking from a maximum at ring 2 and a marked tendency to decrease with increasing distance from the NL/Taracorp lead smelter. However, this variable was usually not predictive of blood lead when other sociodemographic variable were included in the model.

2.7 Individual Child Variables, Including Age and Behavior

2.7.1 Age Distribution

Table 4 shows the age distribution as a function of distance from the NL/Taracorp smelter, and the mean age of children in each ring. The age distribution is shown in Figure 17. Note that there seems to be relatively little dependence of age on distance, so that the inclusion of age in a model for blood lead is not expected to confound the relationship of blood lead with environmental lead in subsequent analyses.

2.7.2 Time Spent in Various Activities

Data were available on individual child activities, including the number of hours per week spent at home, the number of hours per day spent playing outside the house, the number of hours per day spent playing on the floor, and the number of hours per day spent sleeping. The first three of these are shown in Table 5, and the mean number of hours spent playing outside shown in Figure 18 as a function of distance from the NL/Taracorp smelter. There is also a systematic decrease in outdoor play with increasing distance from the NL/Taracorp lead smelter. This analysis suggests that soil exposure is likely to be greater for children living in rings 1 to 3, which are close to the NL/Taracorp smelter.

2.7.3 Mouthing of Non-Food Objects

Individual child behavior is important in understanding why children with similar soil lead levels can have very different blood lead concentrations. However, the relevant behavior is not easily captured on a questionnaire. Some useful information may be obtained from items on the mouthing of non-food objects, and on whether the child eats paint chips. These items are coded 1 = "Does this a lot", 2 = "Just once in a while", 3 = "Almost never", 4 = "Never". U.S. EPA has provisionally recoded these into a consumption frequency scale that may be more useful as a numeric predictor of surface soil or dust intake. U.S. EPA recoding is: "Never" = 0 (times per month), "Almost never" = 1 (time per month), "Just once in a while" = 3 (times per month), "Does this a lot" = 10 (times per month). The mean values are shown in Table 5.

2.8 Correlations and Relationships Among Variables

Many multivariate modelling approaches are based on associations among variables. The methods used in many textbooks, are based on simple Pearson correlation coefficients among the numeric variables. U.S. EPA will emphasize this approach in this report. Categorization of variables is often not needed, since it involves some loss of information. Some categorical variables of particular interest, however, include health-based responses such as whether a blood lead concentration exceeds some criterion such as 10, 15, or 20 ug/dl. Another categorization of interest is whether a soil lead concentration exceed some action-based criterion such as 500 or 1000 ppm.

2.8.1 Correlation Coefficients

Based on preliminary assessments, the list of variables used in U.S. EPA's analyses was reduced to a manageable set of 31 variables. They may be characterized as follows, using variable names in U.S. EPA's analyses and some recoding for clarity:

• Response variable LOGPBB = natural logarithm of blood lead;

Location LOGDIST = natural logarithm of distance from NL/Taracorp smelter, in rings of about 1/8 mile, coded 1 to 10;

Environmental lead variables:
•LOGPBD = natural logarithm of dust lead concentration;
•LOGPBDL = natural logarithm of dust lead loading;
•LOGPBS = natural logarithm of soil lead concentration;
•LOGPBW = natural logarithm of water lead concentration;
•LOGXRFMN = natural logarithm of average lead paint loading measured by XRF, plus 1;
•LOGCXI = natural logarithm of interior lead paint loading times paint condition, plus 1;
•LOGCXO = natural logarithm of exterior lead paint loading times paint condition, plus 1;
•REFINISH = refinishing or paint removal done within last year (0 = no, 1 = yes);

Demographic and household variables:
•AIRCOND = air conditioner used (0 = no, 1 = yes);
•BLDCONIM = building condition, with imputation (1, 2, or 3 if

not missing; 1.389 if
missing);

- CIGSDAY = number of cigarettes smoked per day;
- EDUCYRS = educational attainment, in years;
- INCOME = total household income, coded 0 to 9 in intervals of $5000;
- LOGDSTLD = natural logarithm of total dust loading;
- LOGYRS = natural logarithm of time at residence, in years;
- NONWHITE = parents Afro-American, Asian, Pacific Islander or Native American (0 if no, 1 if yes);
- NUMSMOKE = number of smokers in household;
- RENT_OWN = rental housing (0 if no, 1 if yes);
- USEDSLAG = slag used as fill on property (0 = no, 1 = yes);

Individual child variables:

- AGE = child's age in years;
- AGE2SQR = (age - 2 years), squared;
- FOLK_MED = folk medicine used (0 = no, 1 = yes);
- HRS_HOME = hours spent at home, per week;
- MOUTHFR = mouthing frequency, coded 0, 1, 3, or 10 for never, almost never, once in a while, a lot;
- OUTPLHRS = hours spent playing outside, per day;
- PAINTFR = frequency of eating paint, coded 0, 1, 3, or 10 for never, almost never, once in a while, a lot;
- PLAYFLR = hours spent playing on floor;
- SEX = child's sex (0= male, 1 = female);
- SUCKTHUM = child sucks thumb (0 = no, 1 = yes);

The correlations involve both household and environmental factors on a household unit level, and individual child factors. U.S. EPA therefore calculated the correlation matrix from the complete child data set, which implicitly weights each household or environmental correlation by the number of children in that household. In U.S. EPA opinion, from a risk assessment perspective, this is an appropriate weighting. Correlations calculated from the household-level data set show little difference, however. The results are shown in the Technical Appendix, Tables A1, A2, and A3. Table A1 shows the simple pairwise Pearson correlation coefficients, Table A2 the number of pairs of children from whom non-missing data were available, and Table A-3 the statistical significance or P-value of the correlation.

Any single pairwise correlation coefficient is difficult to interpret by itself because the variables are highly inter-correlated, and a multivariate approach must be used in order to determine overall patterns of association. Any attempt to interpret individual pairwise correlation coefficient is likely to mislead or confuse the reader who is trying to draw some causal conclusions from these data. Section 3 sets out some basic principles and develops modelling strategies for interpreting these data.

It may be useful to the reader to visualize the strength of the statistical associations described by the pairwise correlation coefficients. We have done this in Figures 19 and 20, which are presented as "scatter plot matrices" (Wilkinson 1992) in order to emphasize the multivariate nature of the data. Figure 19 shows the bivariate scatter plot matrix for the logarithm of blood lead and the logarithms of the four most predictive environmental lead variables in the order of their decreasing predictiveness with blood lead. The plots are shown in "standardized values" or Z-scores so that all figures are shown on about the same scale. Since the correlation coefficient between any two variables (say, X and Y) is the same whatever the order of the variables (X and Y or Y and X), we have reduced the visual clutter by showing only half of the correlation scatter plots; the other half are simply the mirror images of those shown. The correlation of a variable with itself would be plotted as a straight line, and always is a perfect linear correlation of 1.0 (the maximum possible). The bivariate correlation (denoted r) between log(blood lead) and log(dust lead loading) is fairly strong, r = 0.429. There is a great deal of scatter in the plot, since child blood lead depends on many factors other than dust lead, but there is also a strong and highly significant positive relationship. The relationship between log(blood lead) and log(dust lead concentration) is weaker but still very significant, r = 0.314. The direct correlation between log(blood lead and log(soil lead) is weaker yet, r = 0.254, but still just significant. The direct pairwise correlation between log(blood lead) and log(1 + lead paint hazard index) is weakest of all, r = 0.170, and not very significant. This particular transformation was chosen because the lead paint hazard index for houses with no interior lead paint is 0, which does not have a finite logarithm.

The strongest linear correlation coefficient in Figure 19 is that between log(dust lead loading) and log(dust lead concentration), r = 0.824, which is not surprising since there is an exact linear mathematical relationship between them,

- log(dust lead loading) = log(dust lead concentration) + log(total dust loading) - log(1000).

The variability in this scatter plot is attributable to differences in total dust loading among households. The correlations between log(dust lead loading) and log(soil lead concentration) or log(1 + interior lead paint hazard index) is weaker, but still statistically significant.

There is almost an equally strong correlation between log(dust lead concentration) and log(soil lead concentration) or log(1 + interior lead paint hazard index), respectively r = 0.438 and r = 0.433. This is consistent with a causal model in which both soil lead and interior lead paint are significant sources of lead in house dust.

The panels in Figure 19 show that these log-transformed lead variables are found in roughly elliptical clouds of data points, with a few straggling values or "outliers" in each plot. This suggests that standard multivariate statistical methods based on an assumed underlying multivariate normal distribution will be adequate for most analyses, but that some attention must be given to outlying values. This concern was not discussed in the IEHR/IDPH report.

Figure 20 shows the correlations and scatter plots for the five lead variables with the five most likely covariate confounders of the relationship between blood lead and environmental lead: log(total dust loading), imputed building condition, decade in which the residence was built, household income, and parental education. The one really strong relationship in Figure 20 is that between log(dust lead loading) and log(total dust loading), which reflects an underlying exactly linear mathematical relationship in which variability is due only to differences in log(dust lead concentration). While higher levels of soil lead and lead paint are found in older houses closer to the NL/Taracorp lead smelter, the correlations of housing age with blood lead and dust lead are much weaker. This shows that the actual dust lead loading as an index of lead exposure is a better predictor of blood lead than is housing age, since it includes information about both the amount of lead in dust and the amount of dust on the floors of the child's residence. The logarithm of total dust loading is therefore correlated moderately well with log(blood lead) because it is a component of log(dust lead loading), but log(total dust loading) is virtually uncorrelated with log(dust lead concentration), log(soil lead concentration), and log(1 + interior lead paint hazard index). The amount of dust on the floor appears to be a very appropriate index for relating socioeconomic variables and housing condition to child blood lead, but dust loading is not strongly confounded with environmental lead variables, so that it is feasible to evaluate the separate effects of different lead sources on childhood lead exposure.

Finally, the importance -- and difficulty -- of showing data in more than two dimensions is illustrated in Figure 21. In this three-dimensional display we illustrate the most important relationships among blood lead, dust lead loading, and soil lead. Much of the variability in log(blood lead) is attributable to differences in dust lead loading, with a smaller but not insignificant increase in blood lead associated with differences in soil lead, over and above those differences attributable to dust lead loading. All of the statistical analyses described in Sections 4, 5, and 6 elaborate these ideas. A multiple linear regression model for log(blood lead) vs. Log(dust lead loading) and log(soil lead) is a mathematical procedure for producing a simple approximate description of the relationship. The mathematical relationship is sketched by the shaded plane that cuts close to most of the blood lead data points, with a few values further away because of inter-individual differences not attributable to the measured quantity of lead in residential soil and dust. The significant effect of dust lead loading is shown by the steep slope of the plane on the log(blood lead) vs. Log(dust lead loading) plane projection. The smaller effect of soil lead is shown by the flatter slope on the log(blood lead) vs. Log(soil lead) plane projection, which is also statistically significant because of the large number of children in the study.

2.8.2 Bivariate Tables for Percentage of Children with Elevated Blood Lead

Grouping of continuous variables such as blood lead or soil lead into categories is usually not necessary and may cost some information. However, sometimes it is easier to understand a relationship by looking at grouped data, especially where the groups are determined by generally recognized public health criteria (such as blood lead), or by regulatory or administrative guidelines such as the range of soil lead remediation levels of 500 to 1000 ppm in the U.S. EPA's former soil lead directive. An example of this is given in Table 6a, which shows the percentage of children with elevated blood lead concentrations (10 ug/dl or greater) for four ranges of soil lead (0-249, 250-499, 500-999, and 1000+ ppm) and three ranges of dust lead concentration, low (0 to 249 ppm), medium (250 to 749 ppm), and high (750+ ppm). The soil cut points reflect the remediation range for lead suggested in U.S. EPA's former soil lead directive (500 to 1000 ppm) as well as a low or baseline range for urban areas (less than 250 ppm). The dust cut points were chosen to provide sufficiently large numbers in each group or cell in the table, but other cut points were evaluated and showed similar trends.

Table 6a shows that when dust lead levels are low, soil lead concentrations show little relationship to blood lead in this data set, probably reflecting that the common soil-to-dust pathway has been controlled to some extent. However, when dust lead levels are in the "medium" range, there is a clear gradient from the percentage at low soil lead (13.5 percent with elevated blood lead) to medium soil lead (23 and 21 percent elevated blood lead) to high soil lead (30 percent above 1000 ppm soil lead). When lead concentrations in house dust are high, the gradient with soil lead is very steep, from 6.7 percent children at low soil lead (< 250 ppm) to 26 percent having elevated blood lead when exposed to soil lead of 500 to 1000 ppm, and 31 percent above 1000 ppm. The increased gradient of blood lead with increasing dust lead is most noticeable in the soil lead category of 500 to 999 ppm, which supports the usual interpretation that soil lead is largely transferred to humans via house dust. This is less clear in the other groups, but due to small or moderate numbers of children in most cells (numbers shown in parentheses), Table 6a should not be over-interpreted.

Similar results are shown in Table 6b for blood lead concentrations of 15 ug/dl or above, and in Table 6c for blood lead concentrations of 20 ug/dl or above. In Table 6b, where dust lead concentrations are sufficiently high to suggest that the indirect exposure pathway from soil through house dust may actually exist for these households, there is a clear increase of elevated blood lead percentages at soil leads of 500 ppm or greater. In Table 6c, the occurrence of highly elevated blood lead concentrations of 20 ug/dl or greater is substantial when soil lead is 500 ppm or greater, but typically only when elevated dust lead concentrations (750 ppm or greater) occur for the indirect exposure pathway.

Table 7 presents a similar display for ranges of dust lead loading and interior lead paint hazard. The lead paint hazard index CXRFIAV is the average of the product of lead paint XRF loading and paint condition number over a number of surfaces inside the housing unit. The ranges of soil lead and lead paint index were chosen to produce sufficiently large numbers of children in each cell in the table. It is clear that there is little evidence of a gradient of the percentage of elevated blood lead with lead paint under most circumstances, whereas there is a clear increase of blood lead with dust lead loading when the lead paint hazard index is either low (< 0.5 mg Pb /sq.cm.) or high (> 5 mg Pb /sq.cm.). The soil lead relationship is flat at medium ranges of the lead paint hazard index (1.5 to 5 mg / sq.cm.).

Certain other anomalies exist in Tables 6a-6c and Table 7, such as the rather high percentage of elevated blood lead for moderate levels of soil lead (250 to 499 ppm) at all ranges of dust lead. It is clear that other factors must be invoked to explain such anomalies in the form of a multivariate relationship. The remainder of this report develops these relationships.

3 CONFOUNDING OF VARIABLES AND IMPLICATIONS FOR MULTIVARIATE STATISTICAL MODELLING

The issue of confounding came up in several contexts: (1) in the draft IEHR/IDPH report of Feb. 1994, and in a subsequent commentary and response by Dr. Maurice LeVois of July 21, 1994 (received by U.S. EPA on January 6, 1995), as a justification for not attempting to include both soil lead and dust lead as predictors of blood lead; (2) as a justification for attributing as much of the variation of blood lead as possible to behavioral and sociodemographic factors, and to environmental factors other than lead. In this section, U.S. EPA will discuss several of the most import aspects of confounding as they affect the Madison County Study:

3.1 Identification of Potential Confounding

Confounding is a potential problem in an epidemiological study. Well-designed studies can minimize the occurrence of confounding. However, even in an observational study with inadequate epidemiological design such as the Madison County study, a post-study analysis of the data finds little evidence that the relationships among blood lead, soil lead, paint lead, and sociodemographic factors are so severely confounded as to preclude quantitative analysis. The effects of soil lead, dust lead, paint lead, sociodemographic and behavioral factors can be estimated separately without excessive loss of information efficiency.

"Confounding" is a term that is widely used in epidemiology and other observational sciences. Confounding occurs when some third variable or factor is related both to the outcome or response being studied—in this case, childhood blood lead—and to the nominal cause of the outcome, such as lead in soil. As noted in U.S. EPA's "Preliminary Assessment" of October 1994, several factors appear to match the decline in mean blood lead with increasing distance from the NL/Taracorp smelter, including decreasing soil lead and dust lead, decreasing housing age and deterioration, increasing parental education and income. These are potential confounding factors.

The most certain way to avoid confounding is to prevent it from happening by designing the study so that possible confounded relationships in the lead-exposed group have at least one corresponding control group without the hypothetical confounding.

In the case of the Madison County study, that would have required identifying a similar community in which there is a gradient of factors such as age of housing, building condition, lead-based paint, ethnicity, income and education with increasing distance from a centrally-located industrial facility, but with no lead-emitting sources that cause elevated levels of lead in soil. There may be many communities of about the same size with substantial points of similarity that may fit this description. The nearby community of Pontoon Beach, Illinois (discussed in the IEHR/IDPH report) may not have been an adequate control group, but it appears that little effort was made to identify any other appropriate community. The design of the IDPH study therefore precluded an easy solution to the confounding problem.

The IEHR/IDPH report and the response by Dr. LeVois then attempt to justify exclusion of related exposure variables from statistical analyses such as multiple regression. This is not, properly, an example of confounding, since soil lead, paint, dust lead concentration, and dust lead loading are simply steps on a causal pathway from source terms (soil, paint) through an intermediate medium (dust) to the child. The existence of this pathway as an important pathway, usually the most important exposure pathway for most children, has been established using a variety of scientific approaches (see discussion below in Technical Appendix A), and has not been disputed by scientific experts. Use of different components of an exposure pathway is discussed in standard epidemiology texts, such as *Modern Epidemiology* by K. Rothman (1986). However, neither the IEHR/IDPH report nor Dr. LeVois's response appear to have quantitatively evaluated the extent of the "confounding" they claim exists in the Madison County Study.

Confounding is a potential problem in this study. Is the problem real? The U.S. Environmental Protection Agency has evaluated quantitatively the amount of confounding, to the extent that it can be defined internally from the data in the study, in the attached Technical Appendix. There are several methods for assessing the consequences of confounding on inferences about relationships between blood lead and other factors. In multiple linear regression models such as used in the IEHR/IDPH report and in some of U.S. EPA's analyses, one technical consequence of confounding is a high degree of collinearity among the predictor variables in the relationship. An example of a perfectly collinear relationship is that between the logarithms of dust lead concentration, dust lead loading, and total dust loading. That relationship is given by:

- log(dust lead loading) = log(dust lead concentration) + log(total dust loading) - log(1000)

where the factor of 1000 arises from combining dust lead loading measured in units of ug Pb/sq.m. and dust lead concentration in units of ug Pb/g dust with dust loading in units of mg dust/sq.m. The amount of collinearity and the components of a collinear relationship are easily identified by a principal components analysis of the correlation matrix of predictor variables (D. Belsley, E. Kuh, and R. Welsch, *Regression Diagnostics*, 1981). In fact, almost any statistical software package that is currently available, including SAS and SYSTAT as used by U.S. EPA and by the writers of the IEHR/IDPH report, contains a great variety of regression diagnostic indicators of collinearity. The authors of the IEHR/IDPH reports and subsequent reports must have not used these diagnostics. The collinearity diagnostics among the 30 most plausible predictors have shown that collinearity as a serious problém only occurs under four conditions:

1. When the logarithms of dust lead loading, dust lead concentration, and total dust loading are all used in a regression model, there is a perfect collinearity as shown above;

2. The shifted logarithm of the variable CXRFIAV, the mean of the product of paint condition and XRF lead loading on interior surfaces, is highly correlated with the logarithm of

the mean XRF, and using both in a regression model causes a loss of information efficiency;

3. AGE is highly correlated with AGE squared, and using both in a model is less desirable than using other variables for age effects; and

4. there is a fairly strong correlation between soil lead and distance from the NL/Taracorp lead smelter, with the geometric mean soil lead within each distance ring being nearly inversely proportional to the distance of the ring from the NL/Taracorp smelter. This last result may be written in the form

• soil lead = (constant) / (distance from NL)

or, taking logarithms on both sides of this equation

• log(soil lead) = log(constant) - log(distance)

which is a fairly strong collinearity. The value of the constant is estimated as about 1300 ppm. If these combinations are avoided, then there are no severe collinearities and the effects of most other predictors or covariates can be estimated separately in joint regressions with only a modest degree of variance inflation.

Household covariates are responsible for part of the variation in blood lead, and including demographic covariates such as race or ethnicity, parental education or home ownership in a model will generally reduce the unexplained variance in blood lead. These variables are not so highly correlated with soil lead, however, and are therefore weak confounders of the relationship.

Almost all statistical modelling procedures in statistical packages currently available can generate the estimates of the correlations among the regression coefficients. The linear regression models can generate exact correlation coefficients even for small samples. Large-sample correlation coefficients among the regression coefficients were calculated for nonlinear regression models, linear and nonlinear structural equation models or equation systems; with sample sizes of 360 to 450 children from the analyses, these correlation coefficients are valid. In models U.S. EPA tested, the correlations of the blood lead regression coefficient estimates were not close to 1 in magnitude even when ostensibly correlated covariates such as log(dust lead loading) and log(soil lead) were both used as predictors of log(blood lead). Similarly low values of the correlation of regression coefficients for most other factors were found, as noted above. Therefore, the regression coefficients for different predictive factors have only a modest degree of overlap, and the statistical models are generally capable of sorting out the effects of different factors. The only consistent exception appeared to involve soil lead and distance from the NL/Taracorp lead smelter; including one of these variables generally left the other variable statistically non-significant. Even when dust lead loading was used in the regression models as a predictor for blood lead, the soil lead coefficient was statistically significant or marginally significant in all of the models described below.

Apart from the four conditions to be avoided in models, labelled (i)-(iv) above, no other serious collinearity was noted. However, there was a moderate degree of collinearity combining the logarithms of soil lead concentration , distance, and the number of cigarettes smoked per day in the household. The latter variable is likely to be a surrogate for other sociodemographic factors. Exterior lead paint and building condition also played a smaller role in this component. As U.S. EPA noted earlier, exterior lead paint and distance from the NL/Taracorp smelter are good predictors of soil lead. When soil lead is used as a predictor for dust lead, there is little additional information that distance can give about dust lead since soil lead and distance are fairly strongly correlated.

In a non-technical sense, there is only a slight to moderate amount of confounding that can modify the relationship between soil lead and blood lead. For example, there is only relatively modest confounding with dust lead. Within each distance or ring, there is some variation in soil lead concentrations. However, for any soil lead concentration, there are housing units with both lower and higher dust lead concentrations and children with both lower and higher blood leads. Therefore, the interfering effects of dust lead differences (using dust lead as the closest environmental predictor of blood lead on the indirect exposure pathway from soil lead to blood lead) can be minimized. Likewise, sociodemographic factors or building condition are not strongly related to both blood lead and soil lead.

Finally, U.S. EPA notes that there is one additional test of potential confounding effects, and in many applications R.M. Mickey and S. Greenland ("The Impact of Confounder Selection Criteria on Effect Estimation", *American Journal of Epidemiology*, Vol. 129, No. 1, 1989, pp. 125 to 137) have shown that this method is one of the best tests (although not foolproof). The method is to carry out the analyses with and without the potential confounding factor included in the model, and to determine whether or not the estimated effect sizes are substantially different. The IEHR/IDPH report carried out a somewhat similar method in the "hierarchical analysis" whose results were shown in Table 11 of their report, but as U.S. EPA will show in the next section, their approach is incomplete and highly misleading.

In summary, extensive diagnostic analyses of a variety of statistical models find that confounding is a worrisome but not insurmountable problem in estimating separate effects of lead in soil, dust, and paint. Careful analyses of the Madison County data set can adequately characterize the typical contributions of lead in paint to soil, the contributions of leads in soil and paint to lead in household dust, and the separate contributions of soil lead and dust lead to blood lead.

3.2 Hierarchical Tests of Environmental Lead Variables

The IEHR/IDPH report argues that soil lead is an inadequate predictor of blood lead, since adding soil lead to other predictors in a linear regression model increases the coefficient of determination or squared multiple correlation (denoted R-squared) by only 3%. They further argued that it was not appropriate to also include dust lead in the model since dust lead and soil lead are confounded as predictors of blood lead. The U.S. Environmental Protection Agency's analyses have found the following results:

1. Using the same base model as in the IEHR/IDPH report, inclusion of soil lead in a linear regression model greatly reduces the statistical significance of modifying factors such as building condition, with soil lead being the most important or second most important predictor of blood lead in the models;

2. When lead paint is tested in the same way as soil lead, lead paint makes a completely insignificant contribution to blood lead, so that applying the same fallacious approach as used in the IEHR/IDPH report would completely dismiss lead paint as a factor in child blood lead;

3. The use of imputed building condition as done in the IEHR/IDPH report provides the least predictive baseline model for hierarchical models among several approaches to the problem of missing values of exterior building condition;

4. The use of dust lead loading nearly doubles the amount of variance in log(blood lead) that is predicted by the regression model, but soil lead makes an additional statistically significant contribution to blood lead over and above that of dust lead, without substantially changing the estimated effect of dust lead, which suggests that confounding of soil lead or dust lead effects on blood lead is moderate but not excessive; and

5. The estimated effects of dust lead are somewhat exaggerated because of the high influence of a few houses with extremely elevated dust lead concentrations (greater than about 8,000 to 10,000 ppm—see next section), but similar estimates are obtained even when the data set is restricted to dust lead concentrations below 1000 ppm.

In order to explain these ideas, some use of mathematical expressions will be helpful. The baseline model used in the "hierarchical analysis" in the IEHR/IDPH report may be written in the form:

- baseline log(blood lead) = B0 + BW log(water lead) + BXI log(CXRFIAV+1) + BXO log(CXRFOAV) + BCOND * BLDCONIM + BREF * REFINISH

where

- CXRFIAV = average product of interior lead paint XRF and interior surface condition,
- CXRFOAV = average product of exterior lead paint XRF and exterior surface condition,
- BLDCONIM = exterior building condition (1,2, or 3) if not missing, 1.389 if missing,
- REFINISH = 1 if recent paint refinishing or remodelling, 0 otherwise.

B0, BW, BXI, BXO, BCOND, BREF are regression coefficients to be fitted to data.

The hierarchical model in the IEHR/IDPH report is given by:

- log(blood lead) = baseline model + BS * log(soil lead).

In order to evaluate this model, U.S. EPA carried out several additional tests. These included: (1) also using only observed building condition as a predictor, or building condition in which missing values were imputed by the mean condition in the distance ring; (2) also truncating the data set to dust lead concentrations less than 3,000 or 1,000 ppm; and (3) also testing dust lead concentration and dust lead loading as predictors, with models:

* log(blood lead) = baseline model + BDC log(dust lead concentration)
* log(blood lead) = baseline model + BDL log(dust lead loading)

and

* log(blood lead) = baseline model + BDL log(dust lead loading) + BS log(soil lead).

The results are shown in Tables 8a-8d, omitting results for dust lead concentration. Dust lead concentration was more predictive than soil lead, but less predictive than dust lead loading.

Predictiveness of a multiple regression model will here be characterized by the squared multiple correlation coefficient, denoted R-squared. Other measures such as the "adjusted" R-square may also be used, but the unadjusted R-square has the most direct interpretation as the fraction of variance in log(blood lead) that is attributable to the linear predictor variables.

The least predictive baseline model was the one used in the IEHR/IDPH report (R-square between 0.029 and 0.051), whereas the baseline models using only observed building condition with no imputation (N = 387) were about as predictive (R-square from 0.098 to 0.128) as the models with building condition imputed by distance (N = 441, R-square from 0.104 to 0.133). The U.S. Environmental Protection Agency next observes that including soil lead increased R-square by only about 0.03 to 0.04 over the baseline model, as noted in the IEHR/IDPH report. However, including dust lead loading nearly doubled R-square, increasing R-square by about 0.08 to 0.14. Thus, dust lead loading is by far the most important environmental lead predictor of blood lead.

The U.S. EPA finally notes that the regression coefficients in the model with both dust lead loading and soil lead are somewhat different than in the models that included either dust lead alone or soil lead alone, but that all coefficients were statistically significant and had the correct sign for a causal relationship. When dust lead was included in the model, the soil lead regression coefficient was roughly halved, although still statistically significant or marginally significant (one-tailed P < 0.10). The regression coefficient for log(dust lead loading) decreased slightly when soil lead was included in the model, but remained highly significant. While this demonstrates that there is some degree of confounding between soil lead and dust lead, the estimated effect of dust lead is largely insensitive to the inclusion of soil lead. The fact that the estimated soil lead effect is greatly reduced by including dust lead in the model strongly suggests that dust lead is the "proximate" predictor on the pathway from soil lead to blood lead. Of course, this has been established in many other studies.

A noteworthy fallacy exists in the use of the particular hierarchical regression model in the IEHR/IDPH report which is that both soil lead and interior lead-based paint are significant predictors of dust lead. Forcing interior lead paint (CXRFIAV) into the model before testing soil lead or dust lead has already biased the conclusions, since part of the predictive power of dust lead on blood lead has already been stolen (so to speak) by lead paint. Likewise, since exterior lead paint is a significant component of soil lead, forcing exterior lead paint into the model before soil lead is included has already biased the results towards a lower estimate of the effect of soil lead on blood lead, even if there were no other confounding factors. This can be demonstrated by comparing the "sub-baseline" model

- log(blood lead) = B0 + BW log(water lead) + BCOND (building condition) + BREF (REFINISH)

with the baseline model, as shown in Table 9. Neither the sub-baseline nor the baseline model is very predictive (R-squared for sub-baseline models range from 0.033 to 0.125), but the predictiveness of the sub-baseline model is improved much more by the inclusion of soil lead (increases in R-squared range from 0.024 to 0.059) than by the inclusion of both interior and exterior lead-based paint (increases in R-squared range from -0.002 to 0.018). Dust lead loading produces an even larger effect than soil lead (increases in R-squared range from 0.09 to 0.18). By the same reasoning as used in the IEHR/IDPH report, lead paint should be a much less important source of blood lead than is soil lead. In reality, soil lead and lead paint are the most important primary sources of environmental lead, acting mainly through the indirect dust exposure pathway. While U.S. EPA does not completely endorse the use of hierarchical regression models to evaluate potential confounding effects, it is clear that the IEHR/IDPH report derived incorrect conclusions about the relative importance of blood lead sources from a biased and inadequate application of this approach, and that almost any reasonable alternative approach would quickly have shown the relative importance of dust lead as the "proximate" predictor for soil lead and lead paint.

The same conclusions apply even when a much better baseline model is used. Based on other studies such as those reviewed in the Air Lead Criteria Document (U.S. Environmental Protection Agency, 1986), U.S. EPA has added child age and race as additional factors in the better baseline model. Age has a nonlinear effect on blood lead. Rather than use a parametric model for which there is no theoretical basis, U.S. EPA has converted age into a set of categorical variables. The reference group is children < 12 months of age who probably have very little soil exposure, and whose dust exposure is largely limited to post-9 month crawling behavior. The other categories are coded as binary variables with AGE1 = 1 if the child is 12 to 23 months of age, AGE2 = 1 if age 24 to 35 months, AGE3 = 1 if age 36 to 47 months, AGE4P =1 if age 48 months or older, and = 0 otherwise for each age indicator. The age groups at 1, 2, and 3 years have significantly higher blood lead concentrations. The U.S. EPA has used BLACK as an indicator for Afro-American racial status in the family interview, since this is by far the largest ethnic or racial subpopulation in the study. The non-BLACK group is primarily white, with only 9 Asian, Pacific Islander, or Native American children in the sample. African-American children had significantly higher blood leads (at least 30 percent higher) in all of the models, everything else being equal.

The results are shown in Tables 10a-10c and Table 11. The new baseline model has a much larger R-square, about 0.21. Adding soil lead still increases R-square by only 0.03 to 0.05, but including dust lead increases R-square by about 0.08 to 0.12. Including soil lead in the model reduces the dust lead loading regression coefficient slightly, from about 0.14 to about 0.12, and including dust lead in the model reduces the estimated soil lead regression coefficient from about 0.18 to about 0.10. In spite of the confounding shown by the decrease of the soil lead regression coefficient when dust lead is included in the models, the soil lead coefficients are statistically significant until the data set is truncated at dust lead concentrations of 1000 ppm. Even with restriction of the data to 1000 ppm dust lead, the soil lead coefficient remains marginally significant in spite of losing many cases with high soil lead concentrations from the restricted data set. Dust lead and child age are the most significant predictors of blood lead in all of these models, and lead paint is always an insignificant direct predictor of blood.

3.3 Confounding May Be Introduced by Non-standard Soil and Dust Sampling Protocols

There may be some concerns about the soil and dust sampling protocols that need to be examined. Many other environmental lead studies U.S. EPA has examined include drip-line or house perimeter samples among the soil samples that are composited to obtain a single soil lead concentration that characterizes the yard. The Madison County study used composites of 10 soil sampling locations within a residential yard. No soil samples were taken within the dripline of the housing unit. It is therefore possible that higher soil lead concentrations would have been obtained had the sampling been done so as to include some dripline samples, since dripline samples are more likely to be contaminated by exterior lead-based paint than soils further away from the house. This may explain the low (albeit statistically significant) relationship between exterior lead paint and yard soil. This suggests that lead paint makes a minor contribution to mid-yard soil, but may present a distorted estimate of the risk to a child who resides there, since the child will generally have access to contaminated yard soil within the dripline.

There may be a converse problem with the dust samples. Many other environmental lead studies included residential dust samples collected by vacuum from floor areas. The dust samples are composited and sieved to obtain a single house dust lead concentration (and dust lead loading) that characterizes the child's exposure to fine dust particles that can adhere to the child's hands, and may contaminate the child's food during preparation and consumption. The Madison County study used composite dust samples that were much larger than other studies, typically 3 to 5 g for Madison County residences, and may therefore have required sampling at locations within a residence that would not have been included in other studies. Dust samples collected in the Madison County may have included components collected on window sills or in other locations where one might expect to encounter large paint chips, and even though these paint chips would have been removed during the laboratory analysis, the dust lead concentrations in the fine dust particles and in the larger debris were recomposited mathematically. There may then be some additional confounding between dust lead and interior lead-based paint based on this mathematical recompositing.

3.4 Components In a Causal Pathway Can Give the Appearance of Confounding

The appearance of confounding may arise from the use of both soil lead and dust lead as predictors for blood lead, since they are components on a common causal pathway from soil lead to blood lead. Inferring causality from empirical evidence is a basic issue in all of the observational sciences, not least of all in epidemiology. The causal relationships relating blood lead to environmental lead have been very clearly established by other scientific techniques. Longitudinal studies provide an excellent experimental basis for concluding that changes in soil lead and dust lead concentrations in the environment can produce changes in child blood lead. Reductions in environmental lead exposure leading to reductions in child blood lead may include dust removal (Charney et al. 1983) or combined soil and dust removal (Weitzmann et al. 1993; Aschengrau et al. 1994), where cause (change in environmental lead) clearly precedes effect (greater reduction in blood lead occurs in soil removal group than in control group). Mass balance calculations, and source identification using stable lead isotope methods, also demonstrate that there is a causal pathway among environmental variables, with exterior lead paint and deposition of airborne lead contributing to lead in soil, and with lead in soil, interior lead-based paint, and deposition of airborne particles contributing to lead in household dust. Thus, lead in soil can contribute to child blood directly, when the child ingests surface soil or exterior dust particles, and indirectly, when the child ingests household dust to which soil has contributed some lead. Dust lead cannot be considered merely a confounding factor in assessing the relationship between blood lead and soil lead.

A standard epidemiology text (K. Rothman, *Modern Epidemiology*, 1986, p. 94) is quite clear on this point: "A confounding variable must not be an intermediate step in the causal pathway between exposure and disease [elevated blood lead in this case]. This criterion requires information outside the data. The investigator must decide whether the causal mechanism that might follow from exposure to disease would include the potentially confounding factor as an intermediate step. If so, the variable is not a confounder."

The use of the "hierarchical regression model" in the IEHR/IDPH report (Table 11 of that report) without assessing the role of dust lead is therefore an extremely serious conceptual error in drawing valid scientific inferences from the IDPH Madison County study. The U.S. EPA finds that both dust lead and soil lead play a role in childhood lead exposure, but not the same role. Hierarchical regression models can be applied in circumstances where there is a clear separation between the extra variable being tested, and the variables that have already been used in the preceding model as predictors of blood lead. A correct application of hierarchical regression modelling is given in EPA's Air Quality Criteria for Lead, 1986. A mathematical model for predicting child blood lead was developed based on the National Health and Nutrition Examination Survey (NHANES II) for the 1976 to 1980 period. It was then shown that, after all other terms had been included in the model, reductions in blood lead during this period of time could be well predicted using the corresponding changes in leaded gasoline. It was also shown that this conclusion was not confounded with changes in other variables over time, including the amount of lead used in lead-soldered food cans. Preliminary analyses showed that the leaded gasoline time series shared relatively little variance with other predictors so that it was appropriate to test leaded gasoline after a preliminary model had been developed using other variables. The application of hierarchical modelling to estimate the effect of soil lead on blood lead Madison County study in the IEHR/IDPH report is clearly different from this, since their analysis excludes the "proximate" predictor, dust lead. Several more appropriate methods are available, as was demonstrated in Section 3.2 of this report.

4 REGRESSION MODELS FOR EVALUATING RELATIONSHIPS AMONG BLOOD LEAD, DUST LEAD, PAINT LEAD, SOIL LEAD, AND DISTANCE FROM THE NL/TARACORP LEAD SMELTER

4.1 Introduction

Because of the complex interrelationships among the variables in the Madison County study, simple bivariate models and bivariate correlation coefficients cannot sort out the relative contributions of several covarying factors. Several multivariate procedures were used in U.S. EPA's analyses, including linear and nonlinear regression models, as well as structural equation models (abbreviated SEM) described in Section 5. Sections 4.2 and 4.3 assess the relationships among lead in several environmental media, with particular reference to location of the child's residence relative to the NL/Taracorp lead smelter. Section 4.3 describes several regression approaches for relating blood lead to environmental lead.

4.2 The Relationship of Blood Lead and Environmental Lead to Distance From the Smelter

The U.S. EPA focussed on the relationship of blood lead, dust lead, and soil lead as a function of distance from the NL/Taracorp smelter because distance is the only information in the data set provided to U.S. EPA that is specifically relevant to the location of most of the proposed soil remediation. The IDPH study covered most of Madison County, a much larger area than Granite City. In fact, there is no way of identifying which children in the IDPH data set provided to U.S. EPA actually live in Granite City, or in Madison, or in Venice, or in Eagle Park Acres. These children may have lead exposure sources causing elevated blood lead concentrations, but the sources are quantitatively different in different locations, and will almost certainly require different remedial strategies depending on the properties of the primary lead sources. The remedial approaches may depend on whether the most important source of exposure is soil near the NL/Taracorp lead smelter, or battery casings and other waste material from the pile at isolated locations further away from the NL/Taracorp lead smelter, such as Venice or Eagle Park Acres.

From this point of view, the IEHR report on the IDPH study is not useful since it is not related to any specific part of Madison County, much less to identifiable sources of exposure. The U.S. EPA's reanalyses attempt to adjust for these serious omissions of the IEHR/IDPH report, but U.S. EPA has not been given the data that will allow U.S. EPA to reanalyze the study in the way that is most relevant to remediation.

There are statements in the IEHR/IDPH report implying that the study area has an overall incidence of elevated blood lead that is not remarkably high compared to other urban areas. This argument is based on fallacious reasoning. Statistical dilution (as practiced in the IEHR/IDPH report) is not the solution to lead pollution. There is a clear indication that the incidence of elevated blood lead concentrations is much higher near the NL/Taracorp lead smelter. The U.S. EPA's May 23 memo, based on the map in Figure 1 of the IEHR/IDPH report, shows a much higher incidence of elevated blood lead near the NL/Taracorp smelter and in the "downwind" direction, about 26 percent of households with at least one child with elevated blood lead as opposed to 13 percent in the urbanized areas farther from the NL/Taracorp smelter, and 7 percent of households in a less urbanized area. EPA has not been given access to the data that would allow U.S. EPA to count the number of children with elevated blood lead in each area. The data that were sent to U.S. EPA showed a very definite gradient of elevated blood leads with distance from the NL/Taracorp lead smelter, with the highest percentage of children within rings 4 or 5 (distance of about 1/2 to 5/8 mile from the NL/Taracorp lead smelter). There clearly are childhood lead exposure problems that are localized in the area near the NL/Taracorp lead smelter. Averaging the lead exposure areas with the rest of Madison County conceals the existence of localized high lead exposures near the NL/Taracorp lead smelter.

The U.S. EPA has also evaluated the role of location (as measured by distance from NL) as a potential confounding factor. At any given location (ring or group of adjacent rings surrounding the NL/Taracorp lead smelter), there are some houses with higher levels and some with lower levels of almost any other measured variable in the study: dust lead, paint lead, parental education and income. Of all the variables in the study, none is seriously confounded with distance from the NL/Taracorp lead smelter except for soil lead concentration. The range of soil lead concentrations in any ring is relatively small, so that soil lead and distance are relatively highly correlated with each other. The average soil lead in each ring is very nearly inversely proportional to the distance of the ring from the smelter. In this regard, the soil lead distribution around the NL/Taracorp lead smelter looks very similar to every other lead smelter community U.S. EPA has studied. This does not by itself prove that the smelter was the primary source of the lead in soil. However, the Illinois EPA report of 1983 (IEPA, 1983) demonstrates a combination of soil lead concentration isopleths with elevated air lead concentrations observed near the NL/Taracorp lead smelter when the smelter was operating in the 1970's and early 1980's that leaves little doubt that much of the soil lead was deposited from airborne particles emitted by the smelter, and possibly to a much lesser extent by other nearby particle sources. Since elevated concentrations of lead are highly persistent in undisturbed soils, current high levels of soil lead largely reflect these historic deposits.

However, U.S. EPA has analyzed the relationship between soil lead and the only other plausible source of elevated lead concentration in residential yard soils, deteriorating exterior lead-based paint. The U.S. EPA found that there was a consistent contribution of exterior lead-based paint to soil that was approximately the same at any distance from the NL/Taracorp lead smelter. Similar results were obtained by several different analytical methods (linear and non-linear regression, structural equations modelling). The condition of the building was used as a covariate in many of the analyses, as were other sociodemographic variables, and their interactions were tested. When the estimated contribution of exterior-lead-based paint and building condition were subtracted from the observed soil lead concentration, there remained a large positive fraction of soil lead at most residences that was not explained by lead paint or by building condition. This component could be reasonably attributed to historical deposition of airborne particles emitted by the smelter and dust particles blown off the NL/Taracorp lead smelter. Neither the building condition nor the background term were ever statistically significant. The best-fitting model (smallest residual variance) was a very simple linear model, fitted in log form:

Soil lead concentration = (1333 / distance) + 7.79 CXRFOAV, where distance = ring number 1 through 10, and where CXRFOAV is the average of the exterior XRF lead paint loading times the exterior paint condition. Since CXRFOAV never exceeded 62.3, and was usually much smaller, the typical exterior lead paint contribution to lead in residential yard soil was always less than 500 ppm, usually much less. The remaining term, which depended on the inverse of the distance from the NL/Taracorp lead smelter, was dominant near the NL/Taracorp lead smelter. Estimates of a non-zero intercept or background soil lead concentration were either very small or negative, and was so insignificant that the goodness of fit of the model was reduced negligibly by omitting the background term. There was little evidence of confounding between distance and exterior paint. The U.S. EPA concludes that most of the lead in soil near the NL/Taracorp lead smelter must be attributed to some processes by which lead is transported from the smelter to the surrounding yards. This implies that much of lead in soil near the NL/Taracorp lead smelter will have properties similar to those of other former smelter communities U.S. EPA has studied: high bioavailability and ready transport from surface soil into the household dust.

There are some relatively high soil lead concentrations far away from the NL/Taracorp lead smelter, attributable to lead paint or to other sources such as use of waste materials for fill or for street repair. These locations cannot be confirmed since IDPH has not provided U.S. EPA with any information about the location of these residences. It is likely that these few exceptional cases (4 out of 351 units) are found in places such as Venice Township or Eagle Park Acres.

4.3 Sources of Lead In Household Dust

Most lead experts agree that household dust is a very important medium for childhood lead exposure, and is likely the primary exposure pathway for lead in soil and for lead in interior lead-based paint. Ingestion of exterior dust from soil is a direct exposure pathway to soil lead that may be nearly as important as the indirect pathway from soil through household dust. Direct ingestion of large flakes or chips of deteriorating interior lead paint can have catastrophic consequences when it occurs, but it would appear that ingestion of large paint chips is a highly unusual circumstance in Granite City. Most children are likely to obtain most of their interior lead paint intake from ingestion of fine particles adhering to the child's hands during normal activities on floor, carpets, or furniture contaminated by lead dusts, with paint as only one of the lesser sources contributing to house dust, compared to track-in of soil and deposition of airborne particles.

There have been many assertions that most of the lead in household dust is attributable to interior lead paint. The U.S. EPA's analyses point in a very different direction. In fact, even Table 12 in the IEHR/IDPH report, for all its faults, finds that lead in soil and lead in paint make contributions that are nearly equal in statistical significance. The U.S. EPA analyses suggest that the estimated contribution of soil to dust is greater near than NL/Taracorp lead smelter than is the estimated contribution of interior lead-based paint because the soil lead concentrations near the smelter are very high compared to soil lead concentrations, whereas the interior lead paint hazard index near the site is only moderately higher than it is farther away. This will be demonstrated quantitatively using multiple regression methods.

The U.S. EPA has analyzed the relationship between dust lead and the only other plausible source of elevated lead concentration in household dusts, deteriorating interior lead-based paint. The U.S. EPA found that there was a consistent contribution of interior lead-based paint to dust that was approximately the same at any distance from the NL/Taracorp lead smelter. Similar results were obtained by several different analytical methods (linear and non-linear regression, structural equations modelling). The condition of the building was used as a covariate in many of the analyses, as were other sociodemographic variables, and their interactions were tested. When the estimated contribution of interior-lead-based paint and building condition were subtracted from the observed dust lead concentration, there remained a large positive fraction of dust lead at most residences that was not explained by lead paint or by building condition. This component could be reasonably attributed to lead in yard soil that was transported into the house. The yard soil contained lead from the smelter or waste pile, along with some exterior lead paint particles. Both soil lead and deteriorating interior lead paint were highly significant predictors of dust lead concentration. The building condition was a statistically significant predictor of household dust lead in most of the models U.S. EPA tested, but much less significant than the soil or paint "source" terms. The background term was positive but not statistically significant in most models U.S. EPA tested. The best-fitting model (smallest residual variance) was a very simple linear model, fitted in log form:

- Dust lead concentration = (0.385 Soil lead) + 94.5 CXRFIAV + (82.7 Building condition)

where building condition was coded 1 through 3, and where CXRFIAV is the average of the interior XRF lead paint loading times the interior paint condition. Since CXRFIAV never exceeded 39.4, and was usually much smaller, the lead paint contribution to household dust was often small, but sometimes large. The U.S. EPA also tested distance from the NL/Taracorp lead smelter as a covariate. When distance was included in the model, distance had a statistically insignificant effect on dust lead, apart from its relationship to physically meaningful source terms such as soil lead and interior paint lead, and to building condition as a modifier of effect. In fact, interactions of building condition with soil lead or with distance were also not statistically significant. Interactions of building condition and interior lead paint with distance were marginally significant in some models The U.S. EPA tested.

The U.S. EPA used the prediction equation for lead in household dust to estimate the fraction of dust that was attributable to soil at each house:

- Soil fraction = (0.385 Soil lead) / (Predicted dust lead concentration)
- Paint fraction = (94.5 CXRFIAV) /(Predicted dust lead concentration)

Soil lead is the dominant contributor to lead in household dust in the rings closest to the NL/Taracorp lead smelter. The estimated contribution of soil lead to household dust lead is generally much larger than the paint contribution in rings 1 through 4 or 5, and on average comparable further away from the NL/Taracorp lead smelter. If most of the lead in house dust near the former smelter is derived from lead in soil, and lead in soil near the NL/Taracorp lead smelter was derived from historic smelter emissions, then much of lead in dust near the NL/Taracorp smelter should also have properties similar to those of other former smelter communities U.S. EPA has studied: high bioavailability and ready transport from household surfaces into the child's mouth.

One way to visualize the relative importance of lead in soil is shown in Figure 22. The estimated contribution of soil lead to household dust lead is generally much larger than the paint contribution in rings 1 through 4 or 5, and on average comparable further away from the NL/Taracorp lead smelter.

Here, the percentage of housing units for which the estimated soil lead fraction of house dust lead is greater than the estimated paint lead fraction of house dust lead is plotted. Note that this decreases from a maximum near the NL/Taracorp lead smelter at ring 1 to a minimum at ring 9, but is greater than 50 percent from rings 1 through 8. (See Map 1 for locations). In other words, lead from soil appears to make a greater contribution to household dust lead than does interior lead paint in the majority of houses within about one mile of the NL/Taracorp lead smelter.

4.4 Specification of Regression Models For Blood Lead

The statistical models that are most easily fitted using linear regression programs are linear in log-transformed variables:

Model 1:

$$\log(\text{blood lead}) = \text{constant} + a \log(\text{soil lead}) + b \log(\text{dust lead loading}) + \text{etc}$$

Unfortunately, when used to predict blood lead concentrations, this model is intrinsically multiplicative and nonlinear, implying that the predicted blood concentration is:

- $\text{blood lead} = \exp(\text{constant})\ (\text{soil lead})^{a}\ (\text{dust lead loading})^{b}$

exp (etc.).

Since lead uptake from the environment is believed to be nearly linear at low to moderate intake rates or exposure concentrations, a more plausible biological model is an additive model:

Model 2:

blood lead = constant + A (soil lead) + B (dust lead loading) + etc.

For statistical purposes, Model 2 is best fitted in log-transformed form which is intrinsically nonlinear in the regression parameters A and B. The parameters A and B are slope factors of the form ug/dl blood lead per ug/g soil lead or per ug/g dust lead, whereas the parameters a and b are dimensionless "elasticities" of the form of percent change in blood lead per 1 percent change in soil lead or dust lead respectively. The logarithmic form of Model 2 for statistical estimation is:

- log(blood lead) = log(constant + A (soil lead) + B (dust lead loading) + etc.).

These parameters can be estimated using standard iteratively reweighted least squares programs for nonlinear regression. These methods have been discussed in (U.S. Environmental Protection Agency 1986, 1989a; Angle et al. 1984).

4.5 Stepwise Models for the Logarithm of Blood Lead (Model 1)

Results of fitting Model 1 using a variety of stepwise modelling approaches is shown in Table 12. Values of R-squared of about 0.37 for the logarithm of blood lead can be achieved with any of several parsimonious models, including models with both log(soil lead) and log(dust lead loading) or log(dust lead concentration) as statistically significant predictors.

Results in Table 12 are characterized by the partial regression coefficient b between the variable and log(blood lead), and by the significance level P of the coefficient (two-tailed; half as large when one-tailed tests are appropriate). The lead paint variables LOGCXI and LOGCXO were never retained in stepwise models that included dust lead. This is not to deny that deteriorating lead-based paint is not a potential source of lead exposure, but rather to emphasize that dust lead, as loading or concentration, are almost always better predictors. In the sense of a causal pathway model, U.S. EPA may infer that dust lead is a more proximate source/pathway of childhood lead exposure than is lead-based paint.

In the forward stepwise selection model that excluded DISTANCE as a predictor, the logarithm of the mean of all XRF measurements, LOGXRFMN, was marginally significant ($P = 0.0496$). While water lead concentration was well down on the list of suspected major sources, there was a detectable statistically significant relationship between log(blood lead) and LOGPBW (P between 0.00180 and 0.0127, b between 0.0460 and 0.0561), and between log(blood lead) and REFINISH (P between 0.00107 and 0.00386, b between 0.147 and 0.178)in all of the stepwise models shown here. While building condition was included in all three of these models, with P between 0.0158 and 0.0417, it was not ever as highly significant as suggested in the IDPH report, once the set of predictor variables to be tested included the confounders and covariates identified in Sections 3 and 4. Total dust loading in the house was not selected as a predictor in any of these models; nor in most of the models shown in Table 12. Parental education remained a significant and relatively stable predictor of blood lead, P between 0.0119 and 0.0184, and with a stable regression coefficient b between -0.0387 and -0.0424. The number of cigarettes smoked per day was well correlated with distance, but on an individual child basis was only marginally predictive of blood lead in different children, P between 0.0459 and 0.1217. Renter vs. homeowner status was included in two of three models but with P between 0.1862 and 0.2248, and should probably be omitted from the models. The relationship between log(blood lead) and age is not linear, and in this model is better described as a convex downward quadratic function with a maximum between 1 and 2 or 3 years of age. The number of hours a child spends at home was included in the stepwise models but was not significant by usual standards, P between 0.1199 and 0.1249. On the other hand the number of hours per day that the child spends outside of the house playing was always one of the most significant predictors in these models, $P < 0.00016$. Gender was only selected in one model, and was not a statistically significant predictor.

In summary, linear models for log(blood lead) always included dust lead as a highly significant predictor, usually selecting log(dust lead loading) as a better predictor than log (dust lead concentration) and thus excluding log (total dust loading) as a significant predictor. The logarithm of soil lead, of average lead-based paint, or of deteriorating interior or exterior lead-based paint, were rarely or never selected for inclusion in models, suggesting that these variables are less proximate predictors of blood lead, in general only playing a role insofar as they contribute lead to household dust and thence to the child by hand-to-mouth contact with surface soil or dust. Soil and paint are therefore largely indirect sources, using house dust as a pathway. Although U.S. EPA believes that this modelling approach has less biological plausibility or interpretability than the linear model (Model 2) described in Section 4.2, this is the method that was adopted in the IDPH report. A reasonably directed model specification search would have clearly exposed these relationships, and in fact the IDPH report clearly identifies household dust lead as the most important and significant predictor of blood lead. The IEHR/IDPH report did not examine the role of soil lead as a major source of dust lead, and therefore an important indirect source of lead in blood.

4.6 Linear Models for Blood Lead fitted in Log Form (Model 2)

The relationship between blood lead and lead intake is somewhat nonlinear (Chamberlain 1984, Marcus and Cohen 1988), but only at levels corresponding to soil and dust lead concentrations well in excess of 1000 ug/g. Therefore, a reasonable approximation to the relationship can be obtained by fitting a linear model, in log-transformed form. The low-dose linearity is also predicted by almost any biokinetic model of lead uptake and distribution in the body, hence has a theoretical as well as an empirical basis. The empirical regression coefficients derived in this way can be compared with earlier studies (U.S. Environmental Protection Agency 1986, 1989a). The same general approach to identifying confounders and selecting predictor variables was applied to this problem as well, but the form of the relationship fitted to the data is intrinsically nonlinear in the parameters. There is no stepwise variable selection method in the nonlinear regression procedures in some commonly used statistical packages (SYSTAT, SAS, BMDP), so U.S. EPA used SYSTAT's PROC NONLIN (Wilkinson 1992) on one model at a time. Three models are shown in Table 13. The simplest model is provided to show that child age, residential soil lead and dust lead can only predict about 16 percent of the variability in LOGblood lead, as measured by R-squared. Substantial increases were obtained in the following way. The U.S. EPA first added a set of household, demographic, and behavioral variables to the model as in Section 4. This increased R-squared to 31 percent. Note that even the baseline model has used age as a categorical variable, with five categories: <1 year of age, 1 year, 2 years, 3 years, and 4 to 6 years. The third model reports the results of specification searches in which interaction terms between age category, soil lead, and dust are reported.

Results are shown in Table 13. Even in the simple model, both dust lead loading and soil lead are statistically significant predictors of child blood lead. Blood lead is highest at age 2 years, although baseline blood lead ages 1 to 3 years are somewhat similar. The soil lead regression coefficient of 1.73 ug/dl per 1000 ppm soil lead is very similar to the typical value cited in the EPA Air Lead Criteria document (U.S. Environmental Protection Agency, 1986) of 2.2 ug/dl per 1000 ppm. The dust lead coefficient in earlier work was derived for dust lead concentration, not lead loading. In the second model in Table 13, a number of important demographic and behavioral variables was included. The variables that were significant predictors of blood lead included house dust loading, refinishing or remodelling within the last year, building condition, nonwhite race, parental education, and time spent outdoors. The number of cigarettes smoked per day and the number of hours per week spent at home were not significant and were dropped from the last model in Table 13.

The last model in Table 13 includes the possibility that there may be different soil lead and dust lead loading regression coefficients at different ages. The predictor variables that capture this effect are the interaction variables or products of soil lead (PBS) with each age category < 1 year, 1 to 6 years, and the products of dust lead loading with ages 0, 1, 2, 3, 4 to 6 (denoted PBDL AGE0 etc.). Preliminary tests found that the soil lead coefficients were very similar, and not significantly different among different ages beyond infancy. The soil lead coefficient, adjusted for dust lead loading, is 1.87 ug/dl blood lead per 1000 ppm soil lead, which is even closer to the usual estimate of 2.2 ug/dl per 1000 ppm soil lead at some other urban and lead smelter sites (U.S. Environmental Protection Agency 1986, 1989a). The estimated dust lead loading coefficient was not calculated in these publications, but is here estimated as a decreasing function of age, from 1.77 ug/dl per 1000 ug Pb/sq.m surface area at ages < 12 months, 0.66 ug/dl per 1000 ug/sq.m. at age 1 year, 0.48 ug/dl per 1000 ug/sq.m. at age 2 years, 0.29 ug/dl per 1000 ug/sq.m at age 3 years. Unfortunately standard error estimates were not estimable using the SYSTAT NONLIN procedure due to a nearly singular Hessian matrix for calculating asymptotic errors. Other methods, such as the bootstrap (Efron and Tibshirani 1992), may be used.

5 CAUSAL MODELS OF ENVIRONMENTAL LEAD PATHWAYS

5.1 Causal Pathway Modelling

Rothman (1986) emphasizes that confounding is not appropriate to describe the use of several predictor variables that are indicators of various steps in a pathway model from the nominal causal agent to the response. There is abundant physical evidence that residential soil lead in the yard of a pre-school child contributes to child blood lead. This includes similarities in patterns of stable lead isotopes, calculations of mass balance of lead in environmental media, and—most importantly—when soil lead is removed under conditions in which there is little or no recontamination of household dust from other exterior sources, then there is a significant reduction of child blood lead for children residing there.

The stable lead isotope studies are described by Wesolowski et al. (1983) based on older housing in Oakland, California. Some studies in Boston children described by Rabinowitz (1987). Isotope ratios have been used in some source identification studies (Rabinowitz 1974).

Some mass balance considerations are described by Marcus and Elias (1994), who estimated that a typical house with lead in paint and soil has roughly 1 kg Pb on interior surfaces, 4 kg Pb in paint on exterior surfaces, and 8 kg Pb in the yard, but less than one gram of lead in household floor dust. While dust moves in and out of houses, time scales for dust transport may range from 2 to 10 months (Marcus 1993) so that the direction of causality is clear: Soil and paint may contaminate dust, whereas dust in the house has little effect on soil lead in the yard, with the possible exception of improperly conducted lead paint abatement.

The most important evidence is directly experimental.

Removal of soil at Kellogg, Idaho, has resulted in a reduction of child blood lead exceeding 50 percent (Ian Von Lindern, personal communication, October 28, 1994). The Boston Urban Soil Lead Abatement Demonstration Project resulted in a 15 percent reduction in blood lead in the first year (Weitzmann et al. 1993), with a continuing comparable decline in the next year (Aschengrau et al. 1994).

The U.S. EPA therefore proceeds with modelling the pathways by which soil lead contributes to lead in house dust and to child blood lead. Several models were developed and tested. Models that have been in the research literature for a decade (Bornschein et al. 1985) suggest that the following system of equations is appropriate:

Model 1:

log(blood lead) = a + b log(soil lead) + c log(dust lead loading) + other covariates

- log(dust lead loading) = log(dust lead concentration) + log(total dust loading) - log(1000)
- log(dust lead concentration) = f + d log(soil lead) + e (Deteriorated interior lead paint) + other covariates
- log(soil lead) = g + h (Deteriorated exterior lead paint) + other covariates

The parameters a, b, ..., h are estimated from the data. The U.S. EPA has developed a complementary approach based on a linear model:

Model 2:

blood lead = A + B (soil lead)+ C (dust lead loading) + other covariates

- dust lead loading = (dust lead concentration) * (total dust loading) / 1000

- dust lead concentration = D + E (soil lead concentration) + F (Deteriorated interior lead paint) + other covariates
- soil lead concentration = G + H (Deteriorated exterior lead paint) + Q / (DISTANCE) + other covariates

The parameters A, B, ..., Q and other parameters must also be estimated from the data. Some technical details are discussed in Appendix B.

5.2 Structural Models for the Logarithm of Blood Lead, Dust Lead, and Soil Lead: Model 1

Models were fitted using the structural equations modelling program EQS (Bentler 1994). This program was selected because it allows a very flexible set of parameter and model specifications, except that models must be linear in variables. The general form of the structural model is shown in Figure 23. The best fitting parsimonious model using LOGPBB, LOGPBDL, LOGPBD, and LOGPBS as state variables is shown in Figure 23, and results tabulated in Table 14. The regression coefficients shown in Table 14 are "elasticities". For example, the direct regression coefficient of LOGPBB on LOGPBS is 0.072, which means that a 1% change in soil lead was associated with a change of 0.072 % in blood lead. Standard errors of elasticities are shown in Table 14. Statistical significance is shown on Figure 23 and subsequently by the two-tailed statistical significance of the pathway regression coefficient. Because multiple comparisons and multiple models have been evaluated before this model was selected, the more stringent criteria may be necessary in order to guarantee groupwise significance of the coefficients (Leamer 1978). Figure 23 and Table 14 show the following results. Soil lead and dust lead loading are significant predictors of blood lead. Dust lead loading and water lead are highly significant predictors, as are building condition and several demographic variables including nonwhite race, cigarette smoking, time spent playing outside, and time spent at home. Neither interior nor exterior lead-based paint deteriorating paint are direct predictors of blood lead, but deteriorating exterior lead paint is a highly significant contributor to soil lead. Deteriorating interior lead-based paint is a highly significant predictor of dust lead concentration, which is of course a highly significant predictor of dust lead loading. Soil lead concentration is also a predictor of dust lead concentration and dust lead loading. The most significant predictor of soil lead is distance from the NL/Taracorp lead smelter site, and the elasticity of -1.00 suggests that approximating soil lead (absent its paint lead component) as the inversely proportional to distance from the NL/Taracorp lead smelter would accurately characterize the relationship. This was used to define inverse distance as the appropriate distance metric for the linear model in Section 5.3. There is therefore some indication that soil lead is a significant predictor of blood lead, both by direct and indirect pathways, with the major component of soil lead close to the NL/Taracorp lead smelter not being derived from lead-based paint.

5.3 Linear Models for Blood Lead, Dust Lead, and Soil Lead: Model 2

Models were fitted using the simultaneous equations modelling program SAS PROC MODEL (SAS 1993). This SAS program was particularly useful for fitting nonlinear equations that arose after logarithmic transformation of the linear equations. The general form of the linear structural model is shown in Figure 24 and results tabulated in Table 15. The regression coefficients shown in Table 15 are slope estimates in appropriate physical units: ug/dl for blood lead vs 1000 ppm = 1 mg/g for dust lead or soil lead concentration, ug/dl for blood lead vs. 1000 ug/sq.m = 1 mg/sq.m for dust lead loading, and so on. For example, the coefficient 5.47 between dust lead loading and blood lead means that the coefficient is 5.47 ug/dl per 1 mg/sq.m. lead in dust. Standard errors of coefficients are shown in Table 18. Statistical significance is shown on Figure 24 using the same notation as Figure 23. Sensitivity of the results was tested by truncation of the data set, with relatively little difference in results between the two cases shown in Table 15, truncation at dust leads of 1,500 ppm and 10,000 ppm.

Figure 24 and Table 15 show the following results:

1. Dust lead loading is a highly significant predictor of blood lead, more predictive than dust lead concentration and much more predictive than soil lead;

2. Several demographic and individual behavioral variables were significant predictors of blood lead, including parental education, identification as Afro-American race, time spent playing outside, and recent refinishing or remodeling of painted surfaces. Time spent at home was marginally significant, time playing on the floor and cigarette smoking were non-significant, and dropped from the final model;

3. Building condition was a highly significant predictor of dust loading, but also a significant predictor of blood lead;

4. Water lead was a marginally significant predictor of blood lead;

5. Neither interior nor exterior lead paint hazard index are direct predictors of blood lead;

6. Total dust loading is significantly correlated with some demographic and house variables such as building condition, cigarette smoking, and Afro-American race identification, although the latter is probably a surrogate for community location within Madison County (not provided to EPA);

7. Soil lead concentration and interior lead paint hazard index are highly significant predictors of dust lead concentration;

8. Deteriorating exterior lead paint is a highly statistically significant contributor to soil lead, but a much smaller and much less significant contributor than inverse distance to the NL/Taracorp lead smelter; and

9. Two different methods for parameter estimation were used, with somewhat different quantitative results, but showing nearly the same pattern of significant pathway relationships.

The results of fitting Model 2 again confirm that soil lead is a significant predictor of blood lead, by an indirect pathway through house dust lead loading, with the major component of soil lead close to the NL/Taracorp lead smelter not being derived from lead-based paint.

6 SUMMARY AND CONCLUSIONS: SITE-SPECIFIC PROPERTIES FOR RISK ASSESSMENT

The NL/Taracorp site appears to have properties that are characteristic of other recently inactive lead smelter sites. The areas closest to the NL/Taracorp lead smelter have soil and dust lead concentrations that are highest and fitting to airborne particulates from smelter emissions. These particles are generally easily transported from exterior soil into household dust, and are likely to be small, soluble, and highly bioavailable.

These analyses, plus observation of Granite City neighborhoods closest to the NL/Taracorp lead smelter, show that:

1. There are many young children in the community;

2. Children often play outdoors for much of the day;

3. Residential yards often contain large bare areas without grass cover;

4. Adjacent yards are often not fenced and are readily accessible to young children; and

5. The residential areas are surrounded by industrial areas and by transportation routes that contribute to the total environmental impact on these children.

Therefore, the IEUBK model can be used at this site, with appropriate site-specific input parameters appearing not much different than standard model parameters.

7 EVALUATION OF THE ADEQUACY OF THE IEUBK MODEL FOR PREDICTING

BLOOD LEAD CONCENTRATIONS IN MADISON COUNTY

The computer model known as the Integrated Exposure Uptake Biokinetic (IEUBK) Model for lead in children, version 0.99d, is designed to predict the distribution of blood lead concentrations for children exposed to a specific set of concentrations of lead in the environment and to allow estimation of a protective residential lead soil level. The EPA IEUBK lead Model has been extensively documented in a Guidance Manual, a Technical Support Document on the model parameters and equations. Preliminary validation studies (1994) and more detailed validations have established a wide range of usefulness for the model. The model is based on five broad kinds of scientific evidence:
(1) community epidemiology studies of children at former lead smelter sites and mining sites, and in urban areas;
(2) occupational and community epidemiology studies in human adults; (3) clinical and medical studies of human children and adults; (4) animal toxicology studies, with particular emphasis on species with some specific physiological or anatomical similarity to humans; (5) mechanistic studies on biological or physical processes, such as the rate of dissolution of lead particles.

A number of assessments were done to evaluate the suitability of the IEUBK Model for estimating the distribution of blood lead concentrations in Madison County children. In spite of U.S. EPA's reservations about the adequacy of the study design, U.S. EPA provisionally accepted the data from the Madison County Lead Study as adequate for these assessments. The IEUBK Model was used in batch mode with soil lead, dust lead, and water lead concentrations as input variables, along with the child's age when the study was done in 1991. The basis for model evaluation was comparisons of observed blood lead with predicted geometric mean blood lead. The overall community distribution of observed and predicted blood lead was in reasonable agreement (Figure 31) except for the upper tail of the distribution, where a number of blood lead concentrations were over-estimated by the IEUBK model.

After considerable investigation, EPA determined the difference between observed and predicted blood lead concentrations were far more closely correlated with the dust lead concentration than with any other variables in the data set, including lead in soil and in paint. Further investigation identified the probable cause as the inclusion of large particles with paint chips in the reported dust lead concentrations, with the consequent increase of reported dust lead concentration for most such occurrences since the lead concentration in a chip of lead-based paint would almost surely exceed 0.5 percent lead (5,000 ppm). The U.S. EPA therefore evaluated several alternative model specifications.

The standard alternative to use of measured dust lead concentration in the IEUBK Model is to assume that the dust lead concentration can be calculated as a mixture from other sources with known concentrations. The most important component of the alternative dust model is the assumed contribution of yard soil to house dust, amounting to 70 percent of the soil lead concentration. The U.S. EPA also added a nominal air lead deposition contribution of 10 ppm. Using the IEUBK Model in batch mode with estimated rather than observed dust lead produced a much better fitting blood lead concentration distribution for Madison County children.

Comparisons of goodness of fit are shown in Figure 25. Figure 25 shows a more compelling argument for use of the estimated dust lead concentration rather than the observed concentration. The observed dust lead concentration was divided up into a range of values: 0 to 249, 250 to 499, 500 to 749, 750 to 999, 1000 to 1499, 1500 to 1999, 2000 to 2999, 3000 to 9999, and 10,000+ ppm lead in house dust.

The difference between observed and predicted blood lead averaged less than 2 ug/dl only up to about 750 ppm reported dust lead, then grew larger and larger. On the other hand, the average difference between observed and predicted blood lead was less than 2.4 ug/dl for reported dust lead concentrations up to

10,000 ppm, and the difference above 10,000 ppm was only 10 ug/dl instead of 40 ug/dl. Therefore, within the range of values to be used in risk estimation, the estimated dust lead concentration using the standard assumption provides a much better description of the observed distribution of blood lead concentration than does the use of the reported dust lead concentration. While these analyses confirm the usefulness of the standard assumption (70 percent contribution of soil lead to house dust lead concentration) for risk estimation purposes, additional investigations were performed to assess the apparent lack of predictiveness of the reported dust lead concentrations.

The sources of any deviations between observed and predicted blood lead concentrations should always be investigated, with clear emphasis on study protocols and analytical methods that may account for non-standard input data. As an example of a possible artifact that could affect observed blood lead concentrations, any area with substantial public awareness of a major lead hazard is likely to have some households (probably those nearest the NL/Taracorp lead smelter) that are aware of the hazard, so that the children and their caretakers may make considerable efforts to avoid lead exposure. There was no way to identify any such artifact in the Madison County Lead Study, whether or not it existed.

On the other hand, there was clear evidence of a potential biasing factor in the method for reporting dust lead concentrations. The U.S. EPA believes that the physical evidence of some inflation of dust leads, along with statistical comparison of the use of observed (i.e., reported) and estimated dust lead, show clearly the estimated dust lead is preferable.

Further assessment of the relationships among dust lead concentration in small particles and lead concentration in larger paint chips is continuing. Some of the lead concentrations in the small dust particles were also extremely high, well in excess of 10,000 ppm, suggesting that the biasing effect may not be merely the inclusion of large paint chips in the reported dust lead concentration. A plausible explanation is that the attempt to collect extremely large samples of dust (3 to 5 g per house) may have required collection of samples from locations that do not reflect the current lead transport kinetics and sources for household dust. Typical floor dust samples in the U.S. EPA Urban Soil Lead Abatement Demonstration Project in Baltimore, Boston, and Cincinnati required only 100 to 300 mg of dust, less than one tenth of the quantity defined in the Madison County Protocol. The only way to obtain such a large dust sample in many homes is to collect samples from "historic reservoirs" of lead contamination, for example behind refrigerators or on window sills. Even fine particles from such obscure locations are likely to contain artificially high concentrations of lead from ground-up lead paint particles from which the child is not currently exposed. If the children had actually been exposed to these very high lead concentrations from ground-up paint chips, there would have been even more observed cases of elevated blood lead. At this time, there is no way by which existing data from the Madison County Lead Study can be used to resolve the uncertainty about the relevance of the dust sampling protocol to actual child exposure.

Note in particular that this evaluation did not require any post hoc calibration or backfitting of IEUBK model parameters to match the data.

Other studies validating the use of the IEUBK model have found that the model provides a very good description of the blood lead distribution at a number of sites, including sites similar to the NL/Taracorp site (K. Hogan, U.S. Environmental Protection Agency, draft memo, Sept. 7, 1995). In fact, one of the validation studies where the prediction was particularly good was done using data from the Madison County Study.

8 SOIL LEAD CLEANUP LEVELS USING THE IEUBK MODEL

Site-specific parameters were based on U.S. EPA's judgement and analyses that the NL/Taracorp site had many points of similarity to the calibration site, Midvale, and that it is appropriate to assume no mitigating factors that may reduce childhood exposure to dust and soil. The standard model parameters with an assumed soil-to-dust coefficient of 70 percent provided a very good fit to the blood lead data, in terms of geometric mean blood lead, percentiles of the blood lead distribution, and reasonable correlation between observed and predicted blood lead.

Sensitivity analyses were based on a range of values for the contribution of lead-contaminated soil to household dust. The default assumption, that the concentration of soil-derived lead in house dust is 0.70 of the soil lead concentration, was judged to be appropriate, and also provided a very good fit to the child blood lead data from the Madison County study. Alternative values in the sensitivity analyses were based on statistical analyses from study data: 0.29 (distances up to 1/4 mile), 0.385 (all data, as discussed in Section 4), and 0.55 (distances to 3/8 mile). The higher dust/soil coefficients of 0.70 and 0.55 are more appropriate for risk assessment, more realistic for properties of the site, and provide a good fit to the data.

Remediation goals for soil abatement were calculated from the IEUBK Model so as to generate not more than 5 percent of children of ages 6 to 84 months with blood lead 10 ug/dl or greater. The calculated soil lead concentrations depended on the assumptions one made about soil to dust transport, but otherwise assumed only default parameters. The soil remediation levels ranged from 350 ppm (soil-to-dust coefficient = 0.70) to 480 ppm (soil-to-dust coefficient of 0.29). This suggests a range of soil lead cleanup values of 350 to 500 ppm. The results are shown in Table 16.

Additional sensitivity analyses were done to assess the effect of lead-based paint on soil lead cleanup levels. As noted in the IEUBK Lead Model Guidance Manual (U.S. Environmental Protection

Agency, 1994), there is very little basis for estimating the "typical" intake of lead from lead-based paint. The Guidance Manual suggests that ingestion of a one-square-inch paint chip may correspond to an intake of about 400 ug Pb. We have assumed that there is some age dependence on paint ingestion that is roughly proportional to the ingestion rate of soil and dust, and have therefore assumed daily intake rates of lead from lead-based paint of 240, 400, 400, 400, 300, 270, and 240 ug Pb per day at ages < 1 year, 1 year, 2 years, 3 years, 4 years, 5 years, and 6 years respectively. However, to start with conservative assumptions about the absorption of lead from lead-based paint, we assumed absorption rates of only 1 percent and 2 percent respectively. This may be reasonable, if paint chips are only partially dissolved in the stomach, or if the lead is contained in some relatively insoluble pigment such as lead chromate. The exact input parameters used in all of the models are presented as IEUBK lead model parameter input files in Appendix D.

Table 17 shows that over the range of soil-to-dust transfer coefficients observed from the Madison County Lead Study, and including the standard assumption of 70 percent that gave the adequate blood lead predictions discussed in Section 7, soil lead cleanup levels are greatly reduced by even a modest intake of lead-based paint, from 230 to 350 ppm if only 1 percent of the lead in the paint is absorbed, and from 115 to 170 ppm if 2 percent is absorbed. These calculations assumed that paint chips are consumed regularly. The IEUBK Model does not presently offer any options to assess the effects of infrequent or sporadic intake of paint chips.

In summary, the use of a range of conditions specific to the NL/Taracorp site has identified a range of soil lead remediation levels that should achieve the specified goal: not more than 5 percent of the children exposed to any specific level can be expected to have a blood lead concentration of at least 10 ug/dl. The upper end of this range, using a site-specific soil-to-dust coefficient, is approximately 500 ppm.

TABLE 1. CHILD BLOOD LEAD AS A FUNCTION OF DISTANCE

Distance	NC	Blood Lead GM	rse (%)	GSD	Percent 10 + ug/dl	Percent 15 + ug/dl	Percent 20 + ug/dl
1	9	8.98	(14)	1.501	33.33	11.11	0.00
2	13	6.46	(18)	1.790	23.08	15.38	7.69
3	63	7.77	(9)	2.015	23.81	19.05	12.70
4	98	6.04	(7)	1.879	19.39	5.10	4.08
5	118	5.69	(6)	1.924	18.64	5.93	3.39
6	81	4.86	(7)	1.835	7.41	2.47	1.24
7	25	5.19	(12)	1.725	12.00	8.00	0.00
8	47	4.44	(8)	1.657	2.13	0.00	0.00
9	22	4.18	(22)	2.584	22.73	0.00	0.00
10	3	3.41	(76)	2.673	0.00	0.00	0.00
Missing	11	4.00	(29)	2.338	9.09	9.09	0.00

GM = Geometric mean blood lead; rse = relative standard error; GSD = geometric standard deviation, and percentage of children with elevated blood lead concentrations, as a function of approximate distance from the NL/Taracorp Lead Smelter at the NL/Taracorp Superfund Site

TABLE 2. SOIL LEAD AND DUST LEAD AS A FUNCTION OF DISTANCE

Distance	Soil Lead, ppm			Dust Lead, ppm			Dust Lead Loading	
	NH	GM	rse	NH	GM	rse	GM	rse
1	6	1501	(17)	6	1410	(38)	0.914	(28)
2	8	1201	(7)	8	611	(51)	0.397	(106)
3	38	541	(10)	39	600	(24)	0.269	(29)
4	66	352	(8)	62	422	(15)	0.239	(20)
5	84	379	(8)	83	409	(13)	0.212	(18)
6	55	251	(7)	55	359	(18)	0.158	(23)
7	19	251	(17)	19	389	(31)	0.159	(35)
8	35	222	(11)	35	326	(16)	0.130	(21)
9	18	180	(17)	18	222	(31)	0.139	(52)
10	2	481	(282)	2	566	(195)	0.143	(238)
Missing	7	73	(50)	7	97	(34)	0.017	(64)

Geometric means (GM) of soil and dust lead concentrations, number N of households, relative standard errors (rse) in percent, as a function of the approximate distance from the NL/Taracorp lead smelter at the NL/Taracorp Superfund Site. Distance is measured in intervals of approximately 1/8 mile.

TABLE 3. HOUSEHOLD DEMOGRAPHIC CHARACTERISTICS AS A FUNCTION OF DISTANCE

Distance	NH	Mean Year Built	Mean Cigs./ Day	Mean Education	Mean Bldg. Cond.	Pct. Non-White	Pct. Renters	Pct. Air Cond.	Mean No. Child.
1	6	1908	16.8	12.5	1.25	11.1	50.0	33.3	1.50
2	8	1926	37.2	11.7	2.00	15.4	62.5	11.1	1.44
3	38	1926	25.0	12.1	1.63	4.8	65.0	17.5	1.58
4	66	1937	25.6	12.5	1.50	13.3	50.8	19.4	1.46
5	84	1935	19.8	12.3	1.40	18.3	50.6	13.4	1.34
6	55	1935	11.2	12.7	1.20	34.6	54.5	10.5	1.42
7	19	1937	14.3	13.0	1.21	28.0	26.3	10.5	1.25
8	35	1936	9.2	12.9	1.06	30.4	28.6	2.8	1.31
9	18	1940	8.1	12.8	1.18	31.8	31.2	0.0	1.22
10	2	1950	5.0	14.0	1.00	0.0	50.0	0.0	1.50
Missing	7	1939	16.4	14.0	1.00	0.0	16.7	0.0	1.38

Numerical characteristics of households as a function of distance the NL/Taracorp lead smelter at the NL/Taracorp Superfund Site, where distance is measured in intervals of about 1/8 mile. Results reported as mean or percent of households.

TABLE 4. AGE DISTRIBUTION OF CHILDREN AS A FUNCTION OF DISTANCE

		Age					
Distance	NC	< 1 year	1 year	2 years	3 years	4 to 6 years	Mean Age
1	9	0.0	11.1	22.2	22.2	44.4	3.93
2	13	0.0	23.1	0.0	15.4	61.5	4.12
3	63	12.7	15.9	17.5	14.3	39.7	3.22
4	98	8.2	14.3	17.4	18.4	41.8	3.45
5	118	10.2	16.9	21.2	18.6	33.1	3.27
6	81	12.3	13.6	19.8	13.6	40.7	3.44
7	25	8.0	12.0	12.0	4.0	64.0	3.92
8	47	10.6	19.1	27.7	8.5	34.0	3.22
9	22	13.6	4.5	22.7	22.7	36.4	3.49
10	3	0.0	0.0	66.7	0.0	33.3	3.60
Missing	11	9.1	18.2	45.5	9.1	18.2	2.47

Percent of children in different age groups as a function of approximate distance from the NL/Taracorp lead smelter at the NL/Taracorp Superfund site, where distance is measured in intervals of about 1/8 mile.

TABLE 5. BEHAVIORAL CHARACTERISTICS AS A FUNCTION OF DISTANCE

Distance	N	Mean Outside Hours	Mean Floor Hours	Mean Mouthing Score
1	9	3.67	4.22	2.33
2	13	3.23	7.69	2.62
3	63	3.87	5.95	2.32
4	98	3.17	6.62	2.26
5	118	2.92	6.28	2.34
6	81	2.57	5.16	2.31
7	25	2.40	5.96	2.60
8	47	2.60	6.04	2.21
9	22	2.09	5.62	2.64
10	3	1.33	3.67	1.67
Missing	11	3.55	7.36	2.46

Mean of individual behavioral characteristics as a function of distance from the NL/Taracorp lead smelter at the NL/Taracorp Superfund site, in intervals of about 1/8 mile.

TABLE 6. PERCENTAGE OF ELEVATED BLOOD LEAD DEPENDS ON BOTH SOIL LEAD AND DUST LEAD CONCENTRATIONS.

TABLE 6A: BLOOD LEAD AT LEAST 10 μg/dl

		Soil Lead			
		0-249	250-499	500-999	1000+
Dust	0-249	3.7 (4/104)	17.2 (11/64)	7.1 (1/14)	33.3 (1/3)
Lead	250-749	13.5 (5/37)	23.2 (13/56)	20.7 (12/58)	30.0 (3/10)
	750 +	6.7 (1/15)	17.8 (8/45)	25.8 (8/31)	30.8 (8/26)

TABLE 6B: BLOOD LEAD AT LEAST 15 μg/dl

		Soil Lead			
		0-249	250-499	500-999	1000+
Dust	0-249	1.0 (1/104)	4.7 (3/64)	0 (0/14)	0 (0/3)
Lead	250-749	5.4 (2/37)	7.1 (4/56)	10.3 (6/58)	10.0 (1/10)
	750+	6.7 (1/15)	4.4 (2/45)	16.1 (5/31)	19.2 (5/26)

TABLE 6C: BLOOD LEAD AT LEAST 20 μg/dl

		Soil Lead			
		0-249	250-499	500-999	1000+
Dust	0-249	0 (0/104)	3.1 (2/64)	0 (0/14)	0 (0/3)
Lead	250-749	5.4 (2/37)	0 (0/56)	3.4 (2/58)	0 (0/10)
	750+	6.7 (1/15)	4.4 (2/45)	16.1 (5/31)	11.5 (3/26)

TABLE 7. PERCENTAGE OF ELEVATED BLOOD LEAD INCREASES WITH DUST LEAD LOADING, BUT IS NEARLY INDEPENDENT OF INTERIOR LEAD PAINT HAZARD INDEX

TABLE 7A: BLOOD LEAD AT LEAST 10 μg/dL DUST LEAD LOADING, μg/m²

Interior		0-249		250-499		500-999		1000+	
Lead Paint	<0.5	5	(7/134)	26	(9/34)	38	(3/80)	29	(2/7)
Hazard Index	0.5-4.9	10	(11/107)	24	(11/46)	19	(5/26)	36	(15/42)
μg/cm²	5+	5	(1/21)	14	(1/7)	38	(3/8)	38	(8/21)

TABLE 7B: BLOOD LEAD AT LEAST 15 μg/dL DUST LEAD LOADING, μg/m²

Interior		0-249		250-499		500-999		1000+	
Lead Paint	<0.5	0	(0/139)	8.8	(3/34)	25	(2/8)	29	(2/7)
Hazard Index	0.5-4.9	3.7	(4/107)	6.5	(3/46)	7.7	(2/26)	17	(7/42)
μg/cm²	5+	4.8	(1/21)	0	(0/7)	0	(0/8)	29	(6/21)

TABLE 7C: BLOOD LEAD AT LEAST 20 μg/dL DUST LEAD LOADING, μg/m²

Interior		0-249		250-499		500-999		1000+	
Lead Paint	<0.5	0	(0/139)	2.9	(1/34)	12.5	(1/8)	29	(2/7)
Hazard Index	0.5-4.9	1.9	(2/107)	0	(0/46)	3.8	(1/26)	9.5	(4/42)
mg/cm²	5+	4.8	(1/21)	0	(0/7)	0	(0/8)	24	(5/21)

TABLE 8. SENSITIVITY OF LINEAR REGRESSION MODEL FOR LOG, BLOOD LEAD TO MODEL SPECIFICATION USING BASELINE AND HIERARCHICAL MODELS

TABLE 8A: COEFFICIENT OF DETERMINATION R^2

Data Subset	All			Dust Lead Conc. < 3000 ppm			Dust Lead Conc. < 1000 ppm		
Building	BLDCONIM	BLDGCOND	BLDGCIMP	BLDCONIM	BLDGCOND	BLDGCIMP	BLDCONIM	BLDGCON D	BLDGCIM P
Condition Model	Grand Mean	No Impute	Distance Mean	Grand Mean	No Impute	Distance Mean	Grand Mean	No Impute	Distance Mean
Regression Model									
Baseline	0.051	0.128	0.133	0.041	0.098	0.105	0.029	0.109	0.104
+ Soil Lead	0.091	0.168	0.161	0.080	0.146	0.133	0.067	0.157	0.133
+ Dust Pb Load	0.197	0.215	0.228	0.156	0.183	0.189	0.171	0.208	0.201
+ Soil + Dust	0.209	0.233	0.238	0.169	0.205	0.200	0.182	0.229	0.212

TABLE 8B: LOG DUST LEAD LOADING REGRESSION COEFFICIENT

Regression Model									
Base	-	-	-	-	-	-	-	-	-
+ Dust PbL	0.176	0.139	0.148	0.174	0.150	0.153	0.199	0.170	0.172
+ Soil + Dust	0.164	0.125	0.129	0.158	0.131	0.139	0.186	0.151	0.160

TABLE 8C: LOG SOIL LEAD REGRESSION COEFFICIENT

Regression Model									
Base	-	-	-	-	-	-	-	-	-
+ Soil Pb	0.191	0.190	0.158	0.185	0.201	0.284	0.182	0.201	0.157
+ Soil + Dust	0.098	0.123	0.092	0.105	0.134	0.096	0.091	0.127	0.088

TABLE 8D: BUILDING CONDITION REGRESSION COEFFICIENT

Regression Model									
Base	0.141	0.329	0.348	0.124	0.305	0.321	0.124	0.334	0.337
+ Soil Pb	0.081	0.288	0.311	0.068	0.264	0.284	0.071	0.293	0.305
+ Dust PbL	0.101	0.225	0.231	0.104	0.236	0.243	0.090	0.229	0.228
+ Soil + Dust	0.066	0.207	0.215	0.0[illegible]	0.215	0.224	0.059	0.213	0.215

TABLE 9. SENSITIVITY OF LINEAR REGRESSION MODEL FOR LOG, BLOOD LEAD TO MODEL SPECIFICATION USING 'SUB-BASELINE' AND HIERARCHICAL MODELS

TABLE 9A: COEFFICIENT OF DETERMINATION R^2

Data Subset	All			Dust Lead Conc. < 3000 ppm			Dust Lead Conc. < 1000 ppm		
Building	BLDCONIM	BLDGCOND	BLDGCIMP	BLDCONIM	BLDGCOND	BLDGCIMP	BLDCONIM	BLDGCOND	BLDGCIMP
Condition Model	Grand (Mean)	(No Impute)	(Distance Mean)	Grand (Mean)	(No Impute)	(Distance Mean)	Grand (Mean)	(No Impute)	(Distance Mean)
Regression Model									
Sub-Base	0.033	0.122	0.125	0.036	0.098	0.102	0.027	0.109	0.102
+ Lead Paint	0.051	0.128	0.133	0.041	0.098	0.105	0.029	0.111	0.104
+ Soil Lead	0.092	0.169	0.161	0.084	0.146	0.133	0.065	0.155	0.126
+ Soil + Dust	0.210	0.228	0.236	0.169	0.195	0.195	0.173	0.215	0.197

TABLE 9B: LOG SOIL LEAD REGRESSION COEFFICIENT

Regression Model									
Sub-Base	-	-	-	-	-	-	-	-	-
+ Soil Lead	0.210	0.195	0.165	0.185	0.192	0.153	0.168	0.185	0.134
+ Soil + Dust	0.077	0.109	0.072	0.078	0.114	0.070	0.059	0.103	0.054

TABLE 10. SENSITIVITY OF LINEAR REGRESSION MODEL FOR LOG, BLOOD LEAD TO MODEL SPECIFICATION USING NEW BASELINE AND HIERARCHICAL MODELS

TABLE 10A: COEFFICIENT OF DETERMINATION R^2

Data Subset	All	Dust Lead < 10,000 ppm	Dust Lead < 3,000 ppm	Dust Lead < 2,000 ppm	Dust Lead < 1,000 ppm
Regression Model					
New Base	0.214	0.198	0.197	0.209	0.220
+ Lead Paint	0.224	0.202	0.199	0.210	0.218
+ Soil Pb	0.264	0.242	0.245	0.253	0.255
+ Dust PbC	0.279	0.242	0.242	0.248	0.249
+ Paint + Soil	0.262	0.240	0.243	0.250	0.257
+ Dust PbL	0.318	0.285	0.283	0.288	0.293
+ Paint + Dust	0.318	0.285	0.284	0.288	0.297
+ Soil + Dust	0.333	0.299	0.299	0.302	0.305

TABLE 10B: LOG DUST LEAD LOADING REGRESSION COEFFICIENT

Model					
New Base	-	-	-	-	-
+ Dust PbL	0.142	0.139	0.143	0.142	0.142
+ Paint + Dust	0.144	0.142	0.147	0.147	0.150
+ Soil + Dust	0.124	0.119	0.120	0.120	0.124

TABLE 10C: LOG SOIL LEAD REGRESSION COEFFICIENT

Model					
New Base	-	-	-	-	-
+ Soil Pb	0.195	0.180	0.189	0.179	0.160
+ Paint + Soil	0.181	0.173	01.88	0.180	0.175
+ Dust + Soil	0.104	0.099	0.109	0.103	0.090

TABLE 11. STEPWISE REGRESSION MODEL WITH STRONG AND WEAK CONFOUNDERS OF THE RELATIONSHIP BETWEEN LOG BLOOD LEAD AND LOG SOIL LEAD, AND COVARIATES OF LOG BLOOD LEAD

Model	Forward		Backward		Force First 3		Drop 6 Worst	
R-squared	0.353		0.353		0.353		0.379	
Variable	B	P	B	P	B	P	B	P
LOGPBDL	0.129	0.000	---	---	0.124	0.000	0.114	0.001
LOGDSTLD	---	---	0.139	0.000	0.016	0.703	---	---
BLDCONIM	0.105	0.040	0.103	0.048	0.103	0.048	0.088	0.091
LOGPBD	---	---	0.124	0.000	---	---	0.026	0.540
AIRCOND	---	---	---	---	---	---	---	---
LOGDIST	-0.226	0.001	-0.230	0.001	-0.230	0.001	0.243	0.001
LOGPBS	---	---	---	---	---	---	---	---
CIGSDAY	0.001	0.236	0.001	0.244	0.001	0.244	0.002	0.096
RENT_OWN	0.073	0.200	0.073	0.198	0.073	0.198	0.099	0.091
LOGCXI	---	---	---	---	---	---	---	---
NUMSMOKE	---	---	---	---	---	---	---	---
EDUCYRS	-0.042	0.012	-0.042	0.011	-0.042	0.011	-0.029	0.085
INCOME	---	---	---	---	---	---	---	---
NONWHITE	0.277	0.000	0.270	0.000	0.270	0.000	0.274	0.000
LOGXRFMN	---	---	---	---	---	---	-0.015	0.338
OUTPLHRS	0.050	0.000	0.049	0.000	0.049	0.000	0.051	0.000
AGE2SQR	-0.024	0.000	-0.024	0.000	-0.024	0.000	-0.024	0.000
REFINISH	0.203	0.000	0.204	0.000	0.204	0.000	0.172	0.002
HRS_HOME	---	---	---	---	---	---	0.002	0.149
SEX	---	---	---	---	---	---	-0.067	0.216

TABLE 12. REGRESSION MODELS FOR LOGARITHM OF BLOOD LEAD. LINEAR IN LOG ENVIRONMENTAL LEAD.

Model	Forward Step		Forward-Drop Dist.		Backward-Drop Dist.	
R-squared	0.369		0.363		0.372	
S-squared	0.2834		0.2918		0.2886	
N	413		422		416	
VARIABLE	B	P	B	P	B	P
LOGPBDL	0.126	0.00000	0.140	0.00000	0.120	0.00000
LOGPBD	---	---	---	---	---	---
LOGPBS	---	---	0.097	0.0124	0.071	0.0622
LOGCXI	---	---	---	---	---	---
LOGCXO	---	---	---	---	---	---
LOGXRFMN	---	---	0.0304	0.0496	---	---
LOGPBW	0.0460	0.0127	0.0561	0.00180	0.0545	0.00254
REFINISH	0.178	0.00107	0.147	0.00699	0.160	0.00386
LOGDSTLD	---	---	---	---	---	---
LOGDIST	-0.215	0.00227	---	---	---	---
AIRCOND	---	---	---	---	---	---
BLDCONIM	0.106	0.0417	0.111	0.0280	0.127	0.0158
CIGSDAY	0.00190	0.1217	0.00243	0.0459	0.00239	0.0513
EDUCYRS	-0.0424	0.0119	-0.0387	0.0184	-0.0400	0.0152
LOGINCOM	---	---	---	---	---	---
NONWHITE	0.281	0.00007	0.301	0.00002	0.288	0.00006
NUMSMOKE	---	---	---	---	---	---
RENT_OWN	0.0688	0.2248	---	---	0.0771	0.1862
AGE	0.158	0.0327	---	---	0.184	0.0188
AGE-squared	-0.0317	0.00230	-0.0096	0.00008	-0.0328	0.00209
EATPNTFR	---	---	---	---	---	---
HRS_HOME	0.00184	0.1247	0.00186	0.1199	0.00182	0.1229
MOUTHFR	---	---	---	---	0.0149	0.0914
OUTPLHRS	0.0483	0.00013	0.0574	0.00000	0.0486	0.00015
PLAYFLR	---	---	---	---	---	---
SEX	---	---	---	---	-0.0748	0.1662

TABLE 13. REGRESSION MODELS FOR BLOOD LEAD. LOGARITHM OF LINEAR MODEL FITTED.

Model	Minimal Environment		Minimal Environment + House, Child Confounders		Environment, Age Inter., + House, Child Confounders	
R-squared	0.161		0.314		0.335	
S-squared	0.3868		0.3070		0.3041	
N	463		441		441	
VARIABLE	B	STD.ERR.	B	STD.ERR.	B	STD.ERR.
PBDL	0.557	0.056	0.267	0.027	—	NE—
PBS	1.729	0.473	1.519	0.417	—	NE—
AGE 0	3.07	0.38	2.84	1.67	3.76	NE—
AGE 1	5.30	0.59	4.64	1.87	5.22	NE—
AGE 2	5.52	0.54	4.25	1.85	4.82	NE—
AGE 3	5.10	0.57	3.80	1.87	4.42	NE—
AGES 4-6	3.86	0.41	2.84	1.80	3.56	NE—
PBDL AGE 0	—	—	—	—	1.767	NE—
PBDL AGE 1	—	—	—	—	0.660	NE—
PBDL AGE 2	—	—	—	—	0.482	NE—
PBDL AGE 3	—	—	—	—	0.289	NE—
PBDL AGE4+	—	—	—	—	0.002	NE—
PBS AGE 0	—	—	—	—	-0.149	NE—
PBS AGE 1	—	—	—	—	1.72	NE—
DUST LOAD	—	—	0.847	0.263	0.832	NE—
REFINISH	—	—	0.666	0.271	0.677	NE—
BLDG.COND	—	—	0.893	0.329	0.907	NE—
CIGS/DAY	—	—	0.00110	0.00605	—	—
NONWHITE	—	—	1.176	0.394	1.18	NE—
EDUC.YRS.	—	—	-0.1625	0.0768	-0.1909	NE—
HRS_HOME	—	—	0.00210	0.00555	—	—
OUTPLHRS	—	—	0.2116	0.0720	0.2044	NE—

TABLE 14A. STRUCTURAL EQUATION MODEL FOR BLOOD LEAD AND ENVIRONMENTAL LEAD: REGRESSION PARAMETERS OF MODEL 1.

Response Variable	Predictor Variable	Method	Full Inf. Max. Likelihood				Gen. Method Moments			
		Dust Lead Cutoff	< 10,000		< 1,500		< 10,000		< 1,500	
		Units	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.
Log of Soil Lead Concentration	Intercept	Log (μg/g)	7.43	0.16	7.45	0.19	7.47	0.14	7.50	0.15
	Log of Distance Ring	Log (μg/g) per Log (ring)	-1.049	0.076	-1.060	0.090	-1.062	0.067	-1.080	0.072
	Building Condition	Log (μg/g)	-0.004	0.053	-0.012	0.059	0.026	0.037	-0.032	0.042
	Log of Ext. Lead Paint XRF* Condition	Log (μg/g) per Log (mg/cm²)	0.078	0.010	0.076	0.011	0.078	0.009	0.077	0.009
Log of Dust Lead Concentration	Intercept	Log (μg/g)	3.03	0.58	3.53	0.52	1.95	0.60	2.99	0.54
	Log of Soil Lead Conc.	Log (μg/g) per Log (μg/g)	0.497	0.104	0.378	0.093	0.683	0.101	0.468	0.091
	Building Condition	Log (μg/g)	0.083	0.079	0.063	0.069	0.052	0.080	0.066	0.056
	Log of Int. Lead Paint XRF* Condition	Log (μg/g) per Log (mg/cm²)	0.149	0.022	0.092	0.018	0.118	0.022	0.79	0.020

TABLE 14B.

Response Variable	Predictor Variable	Method: Dust Lead Cutoff. / Units	Full Inf. Max. Likelihood < 10,000 Est.	S.E.	< 1,500 Est.	S.E.	Gen. Method Moments < 10,000 Est.	S.E.	< 1,500 Est.	S.E.
Log of Total Dust Loading	Intercept	Log (mg/cm^2)	-1.64	0.38	-1.50	0.41	-1.45	0.38	-1.35	0.40
	Air Conditioner	Log (mg/cm^2)	-0.286	0.133	-0.262	0.148	-0.329	0.114	-0.315	0.131
	Building Condition	Log (mg/cm^2)	0.459	0.080	0.485	0.088	0.326	0.079	0.347	0.088
	Log (Num. Cigs + 1)	Log (mg/cm^2) per Log (Num Cigs)	0.057	0.027	0.044	0.029	0.106	0.025	0.103	0.027
	Log (Yrs. Educ.)	Log (mg/cm^2) per Log (Yrs. Educ.)	0.030	0.027	0.016	0.029	0.025	0.027	0.014	0.029
	Afr-Amer.	Log (mg/cm^2)	0.425	0.111	0.452	0.119	0.279	0.095	0.291	0.098
	Renter	Log (mg/cm^2)	-0.012	0.090	0.000	0.098	0.025	0.081	0.039	0.085

TABLE 14C.

Response Variable	Predictor Variable	Method / Dust Lead Cutoff	Full Inf. Max. Likelihood < 10,000 Est.	S.E.	Full Inf. Max. Likelihood < 1,500 Est.	S.E.	Gen. Method Moments < 10,000 Est.	S.E.	Gen. Method Moments < 1,500 Est.	S.E.
	Intercept	Units	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.
Blood Lead	Age < 12 mos.	Log (μg/dl)	0.46	1.05	0.97	1.14	0.46	1.02	0.74	1.04
	Age 12-47 mos.		0.84	1.04	1.38	1.13	0.77	1.01	1.08	1.04
	Age 48+ mos.		0.56	1.04	1.08	1.13	0.49	1.01	0.79	1.04
	Bldg. Cond. Imputed		0.140	0.67	0.168	0.086	0.089	0.045	0.109	0.052
	Log (No. Cigs)		-0.007	0.017	-0.008	0.019	-0.004	0.018	-.005	0.020
	Renter		0.130	0.056	0.127	0.060	0.141	0.055	0.147	0.058
	Log (Yrs. Educ.)		-0.635	0.192	-0.665	0.197	-0.648	0.187	-0.647	0.199
	Afro-American		0.170	0.072	0.167	0.081	0.175	0.059	0.162	0.058
	Log (Hrs. Outdoor Play)		0.104	0.036	0.110	0.038	0.116	0.029	0.119	0.030
	Log (Hrs. Floor Play)		-0.008	0.041	-0.028	0.044	-0.025	0.040	-0.035	0.041
	Log (Hrs. at Home)		0.292	0.171	0.211	0.183	0.247	0.167	0.205	0.173
	Refinish/Remodel		0.138	0.054	0.132	0.057	0.137	0.048	0.121	0.047
	Log (Water Lead)		0.068	0.031	0.059	0.033	0.071	0.025	0.068	0.027
	Log (Dust Lead Loading)		0.134	0.62	0.124	0.102	0.213	0.039	0.196	0.058

TABLE 15. STRUCTURAL EQUATION MODEL FOR BLOOD LEAD AND ENVIRONMENTAL LEAD: REGRESSION PARAMETERS OF MODEL 2.

Response Variable	Predictor Variable	Method	Full Inf. Max. Likelihood				Gen. Method Moments			
		Dust Lead Cutoff	< 10,000		< 1,500		< 10,000		< 1,500	
		Units	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.
Soil Lead Conc.	Distance Ring	μg/g per 1/ring	1304	55	1269	58	1092	40	1067	39
	Ext. Lead Paint XRF* Condition	μg/g per mg/cm^2	7.9	1.1	8.3	1.2	11.0	1.4	12.4	1.5
Dust Lead Conc.	Intercept	μg/g	1	28	56	26	0	forced	0	forced
	Soil Lead Conc.	μg/g per μg/g	0.874	0.127	0.638	0.098	0.880	0.053	0.934	0.051
	Int. Lead Paint XRF* Condition	μg/g per mg/cm^2	58.3	10.6	24.0	6.5	53.6	12.9	26.9	9.3

TABLE 15B.

Response Variable	Predictor Variable	Method: Dust Lead Cutoff / Units	Full Inf. Max. Likelihood <10,000 Est.	Full Inf. Max. Likelihood <10,000 S.E.	Full Inf. Max. Likelihood <1,500 Est.	Full Inf. Max. Likelihood <1,500 S.E.	Gen. Method Moments <10,000 Est.	Gen. Method Moments <10,000 S.E.	Gen. Method Moments <1,500 Est.	Gen. Method Moments <1,500 S.E.
Total Dust Loading	Intercept	mg/m^2	0.238	0.120	0.198	0.130	0.351	0.094	0.014	0.077
	Air Conditioner (1 = Yes)	mg/m^2	-0.117	0.101	-0.105	0.109	-0.202	0.071	0.069	0.050
	Building Condition	mg/m^2	0.217	0.045	0.242	0.051	0.185	0.047	0.230	0.050
	Number CIGS/Day	mg/m^2 per 100 cigs/day	0.304	0.158	0.264	0.166	0.296	0.083	0.293	0.077
	Afr.-Amer. (1 = Yes)	mg/m^2	0.217	0.065	0.240	0.073	0.195	0.052	0.230	0.052

TABLE 15C.

Response Variable	Predictor Variable	Method Dust Lead Cutoff	Full Inf. Max. Likelihood				Gen. Method Moments			
			< 10,000		< 1,500		< 10,000		< 1,500	
	Intercept	Units	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.
Blood Lead Conc.	Age < 12 mos.	µg/dL	-0.37	4.28	1.07	4.48	-0.59	3.66	4.63	3.93
	Age 12-47 mos.		1.05	4.16	2.52	4.36	0.62	3.59	5.70	3.88
	Age 48+ mos.		-0.43	4.14	1.00	4.34	-0.33	3.59	4.92	3.89
	Building Condition	µg/dL	0.97	0.41	0.94	0.42	0.64	0.30	0.89	0.37
	Renter	µg/dL	0.53	0.29	0.49	0.29	1.47	0.31	1.36	0.32
	Afr. Amer.	µg/dL	0.88	0.40	0.82	0.42	0.56	0.31	0.59	0.30
	Educ. Yrs.	µg/dL per yrs. school	-0.215	0.072	-0.229	0.073	-0.352	0.076	-0.352	0.077
	Refinish/Remodel	µg/dL	0.44	0.27	0.37	0.28	0.57	0.24	0.57	0.22
	Log Hours Home	µg/dL per log (hrs/wk)	0.98	0.80	0.72	0.84	1.21	0.68	0.16	0.72
	Outdoor Play	µg/dL per hrs/day	0.56	0.20	0.57	0.20	0.40	0.16	0.24	0.16
	Water Lead	µg/dL per µg/L	0.052	0.57	0.048	0.059	0.006	0.029	0.027	0.029
	Dust Lead Loading	µg/dL per 1000 µg/m²	1.41	0.51	1.87	0.78	5.47	0.93	5.74	1.54

TABLE 15. STRUCTURAL EQUATION MODEL FOR BLOOD LEAD AND ENVIRONMENTAL LEAD: REGRESSION PARAMETERS OF MODEL 2.

Response Variable	Predictor Variable	Method / Dust Lead Cutoff / Units	Full Inf. Max. Likelihood < 10,000 Est.	Full Inf. Max. Likelihood < 10,000 S.E.	Full Inf. Max. Likelihood < 1,500 Est.	Full Inf. Max. Likelihood < 1,500 S.E.	Gen. Method Moments < 10,000 Est.	Gen. Method Moments < 10,000 S.E.	Gen. Method Moments < 1,500 Est.	Gen. Method Moments < 1,500 S.E.
Soil Lead Conc.	Distance Ring	μg/g per 1/ring	1304	55	1269	58	1092	40	1067	39
	Ext. Lead Paint XRF* Condition	μg/g per mg/cm^2	7.9	1.1	8.3	1.2	11.0	1.4	12.4	1.5
Dust Lead Conc.	Intercept	μg/g	1	28	56	26	0	forced	0	forced
	Soil Lead Conc.	μg/g per μg/g	0.874	0.127	0.638	0.098	0.880	0.053	0.934	0.051
	Int. Lead Paint XRF* Condition	μg/g per mg/cm^2	58.3	10.6	24.0	6.5	53.6	12.9	26.9	9.3

TABLE 16. SENSITIVITY ANALYSIS FOR SOIL LEAD CLEANUP LEVEL, WITHOUT LEAD PAINT

Soil-to-Dust Coefficient	Soil Lead Concentration, ppm
0.20	520
0.29	480
0.385 (all data)	440
0.55	390
0.70	350

TABLE 17. SENSITIVITY ANALYSES FOR SOIL LEAD CLEANUP LEVEL, WITH LEAD PAINT ADDED

	Soil Lead Concentration, ppm	
Soil-to-Dust Coefficient	Paint Absorption 1%	2%
0.29	320	160
0.385 (all data)	290	150
0.55	260	130
0.70	230	115

REFERENCES

Agency for Toxic Substances and Disease Registry, 1994. Comments on Multisite Lead and Cadmium Exposure study with Biological Markers Incorporated. Review draft. Atlanta, Georgia.

Angle C.R., Marcus A.H., Cheng I-H., McIntire M.S.. 1984. Omaha childhood blood lead and environmental lead: A linear total exposure model. *Environmental Research* 35: 160-170.

Aschengrau A., Beiser A., Bellinger D., Copenhafer D., Weitzman M. 1994. The impact of soil lead abatement on urban children's blood lead levels: Phase II results from the Boston Lead-in-Soil Demonstration Project. *Environmental Research* 67: 125-148.

Belsley D., Kuh E., Welsch R. 1980. *Regression Diagnostics*. John Wiley, New York.

Bentler P.M., Wu E.J.C. 1993. *EQS/Windows User's Guide*. BMDP Statistical Software, Los Angeles, CA.

Bornschein R.M., Succop P.A., Dietrich K.N., Clark C.S., Quee Hee S., Hammond P.B. 1985. The influence of social and environmental factors on dust lead, hand lead, and blood lead levels in young children. *Environmental Research* 38: 108-118.

Chamberlain A.C. 1985. Prediction of the response of blood lead to airborne and dietary lead from volunteer experiments with lead isotopes. *Proceedings of the Royal Society of London, Series B* 224: 149-182.

Charney E., Kessler B., Farfel M., and Jackson D. 1983. Childhood lead posioning: A controlled clinical trial of the effect of dust-control measures on blood lead levels. *New England Journal of Medicine* 309: 1089-1093.

Efron B. and Tibshirani R. 1993. *An Introduction to the Bootstrap*. Chapman and Hall, New York.

Greenland S., Schlesselman J.J., Criqui M.H. 1986. The fallacy of employing standardized regression coefficients and correlations as measures of effect. *American Journal of Epidemiology*. 123: 203-208.

Illinois Department of Public Health, 1994. Madison County Lead Exposure Study. Granite City, Illinois. Draft for public comment. Springfield, Illinois, Feb. 1994.

Illinois EPA 1983. Study of lead pollution in Granite City, Madison and Venice, Illinois. Springfield, IL, April 1983.

Marcus A.H., Cohen J. 1988. Modeling the blood lead-soil lead relationship. In: Environmental Geochemistry and Health Monograph Series 4. Lead in Soil: Issues and

Guidelines. (Eds) BE Davies and BG Wixson. Science Reviews Limited, Northwood, England (1988) pp. 161-174.

Marcus, A.H. 1992. Use of site-specific data in models for lead risk assessment and risk management. In Symposium Overview (ed. B. Beck). An Update on Exposure and effects of Lead. Fund Appl Toxicol *18:10-16.*

Marcus A.H.1994. Preliminary assessment of Madison County Lead Study. In-house memo, October, 1994. Submitted during Public Comment period.

Marcus A.H., Hogan K., White P., Van Leeuwen P. 1994. Comments on Madison County Lead Exposure Study, Granite City, Illinois. In-house memo, U.S. Environmental Protection Agency, May 1994; corrected draft, Sept. 18, 1994. Research Triangle Park, NC.

Marcus, A.H., Elias, R.W., *Estimating the Contribution of Lead-Based Paint to Soil Lead, Dust Lead, and Childhood Blood Lead*, in Lead in Paint, Soil, and Dust: Health Risks, Exposure Studies, Control Measures, Measurement Methods, and Quality Assurance, astm stp 1226, Michael E. Beard and S.D. Allen Iske, Eds., American Society for Testing and Materials, Philadelphia, 1995.

Mickey R.M. and Greenland S. 1989 The impact of confounder selection criteria on effect estimation. *American Journal of Epidemiology* 129: 125-137.

Rabinowitz M.B., Kopple J.D., Wetherill G.W. 1976. Kinetic analysis of lead metabolism in healthy humans. *Journal of Clinical Investigations* 58: 260-270.

Rabinowitz M.B. 1987. Stable isotope mass spectrometry in childhood lead poisoning. *Biological Trace Element Research.* 12: 223-229.

Rothman K. 1986. *Modern Epidemiology*. Little, Brown & Co. Boston.

SAS (Statistical Analysis System) ETS (Econometrics and Times Series Programs). 1993. Release 6.03. PROC MODEL. SAS Inst. Cary, NC.

Stark A.D., Quah R.F., Meigs J.W., DeLouise E.R. 1982. The relationship of environmental lead to blood lead levels in children. *Environmental Research* 27: 372-383.

Stellman, S.D. 1987. Confounding. *Preventative Medicine* 16: 165-182.

USEPA 1986. *Air Quality Criteria for Lead* (4 vols). Report EPA-600/8-83/028cF. Environmental Criteria and Assessment Office, Research Triangle Park, NC.

USEPA 1989. Review of the National Air Quality Standards for Lead: Exposure Analysis Methodology and Validation, OAQPS Staff Report, EPA-450/2-89-011, June 1989. Principal author, J. Cohen. Contributing authors, Marcus AH, Sledge D, McLamb D, Brion

G, Haines J. See esp. Appendix B.

USEPA 1994a. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children, Publication EPA/540-R93/081, Office of Emergency and Remedial Response, Washington DC, Feb. 1994.

USEPA 1994b Technical Support Document: Parameters and Equations Used in the Integrated Exposure Uptake Biokinetic Model for Lead in Children (v 0.99d). Publication EPA/540/R-94/040. Office of Emergency and Remedial Response, Washington, DC. July 1994.

USEPA 1994c. Validation Strategy for the Integrated Exposure Uptake Biokinetic Model for Lead in Children, Publication EPA/540-R94/039, Office of Solid Waste and Emergency Response, Washington DC, Dec. 1994.

Von Lindern, I. Oct. 28, 1994. Personal communication.

Weitzman M., Aschengrau A., Bellinger D., Jones R., Hamlin J.S., Beiser A. 1993. Lead contaminated soil abatement and urban children's blood lead levels. *Journal of the American Medical Association*. 269: 1647-1654.

Wilkinson L. 1992. *SYSTAT: The Package for Statistics*. SYSTAT Inc., Evanston, IL.

Yaffe Y., Flessel C.P., Wesolowski J.J., del Rosario A., Guirguis G.N., Matias V. Et al. 1983. Identification of lead sources in California children using the stable isotope ratio technique. *Archives of Environmental Health* 38: 237-245.

Figure 1. Percentage of children with elevated blood lead (10 ug/dl or above) decreases with increasing distance from the NL/Taracorp lead smelter. Bars show one standard error of percentage estimate.

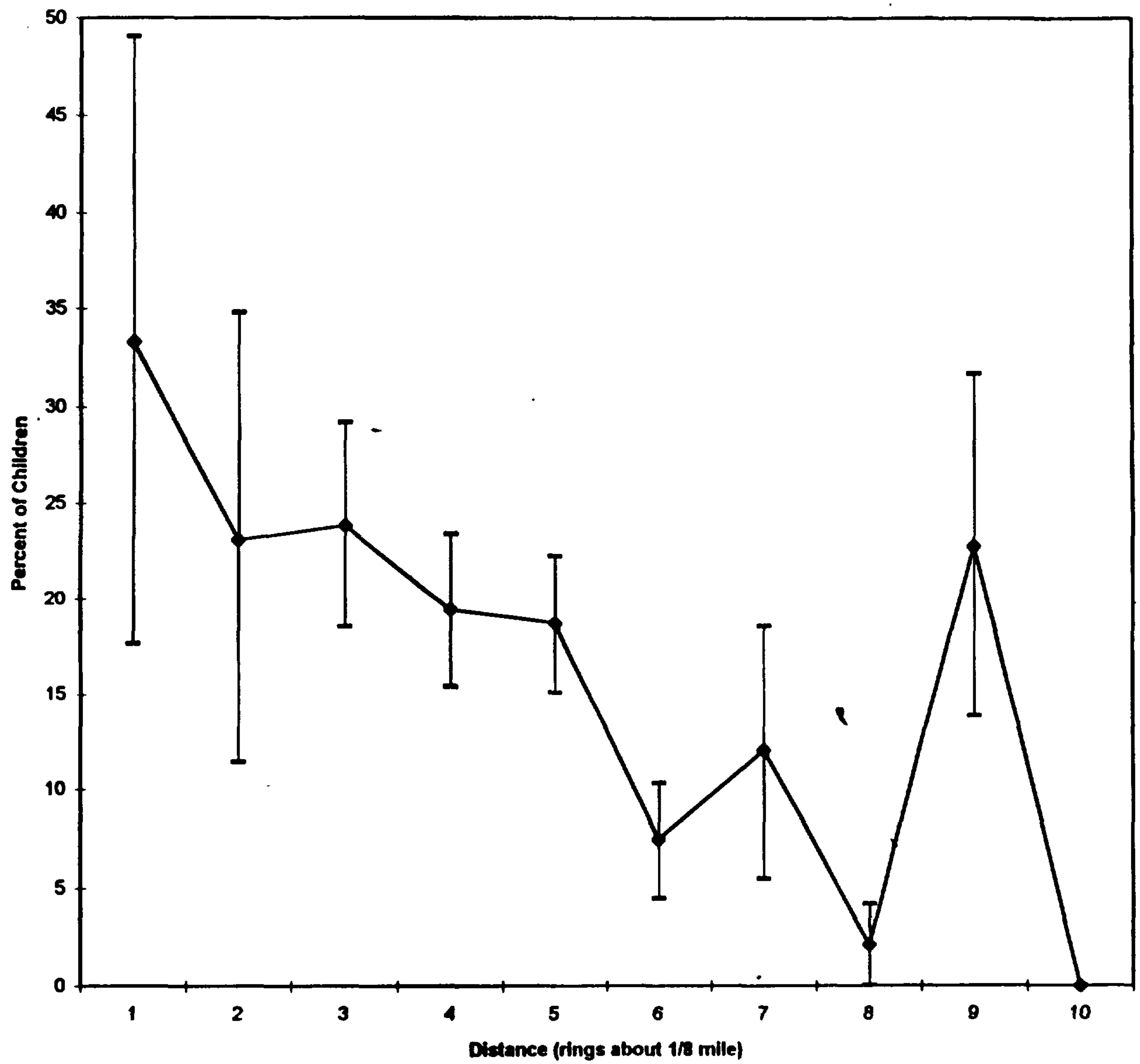


Figure 2. Percentage of children witl y elevated blood lead (15 ug/dl or above) decreases with increasing distance from the NL/Taracorp lead smelter. Bars show one standard error of percentage estimate.

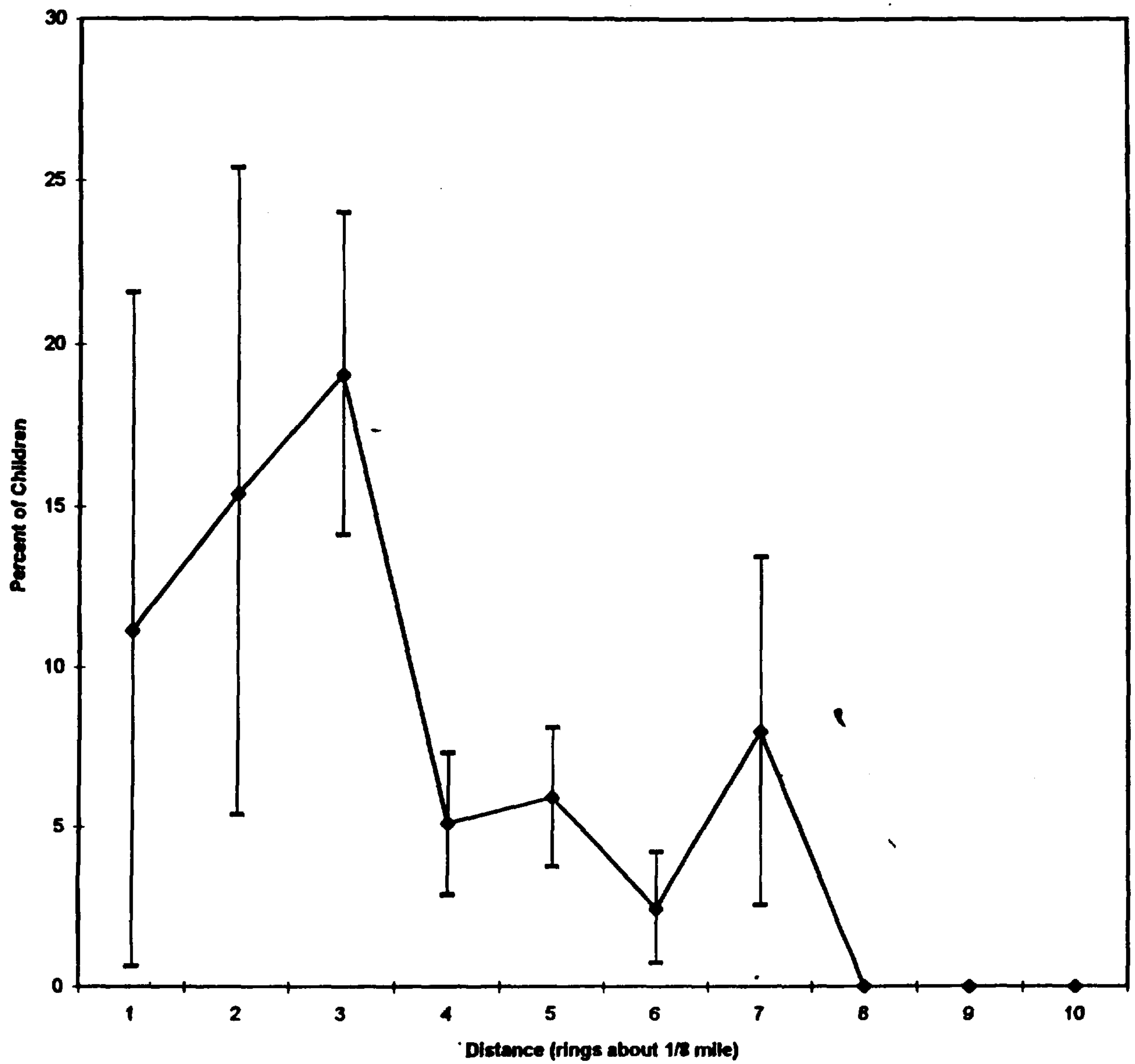


Figure 3. Percentage of children with blood lead sufficiently high to require immediate individual intervention (20 ug/dl or above) decreases with increasing distance from the NL/Taracorp lead smelter, beyond ring 3. Bars show one standard error of percentage estimate.

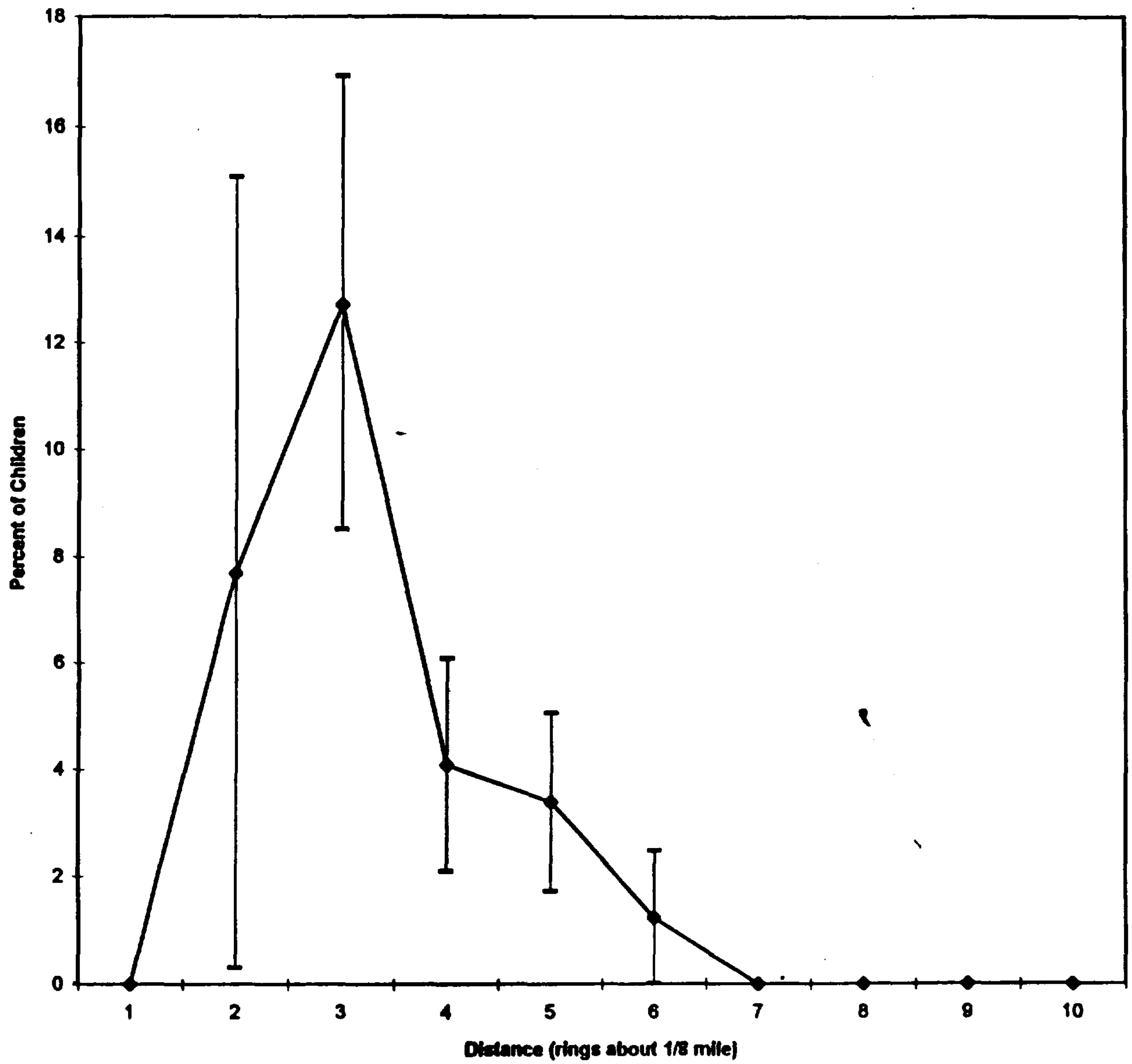


Figure 4. Geometric mean blood lead concentration of Madison County children decreases with increasing distance from the NL/Tara lead smelter. Bars show one geometric or relative standard error of geometric mean.

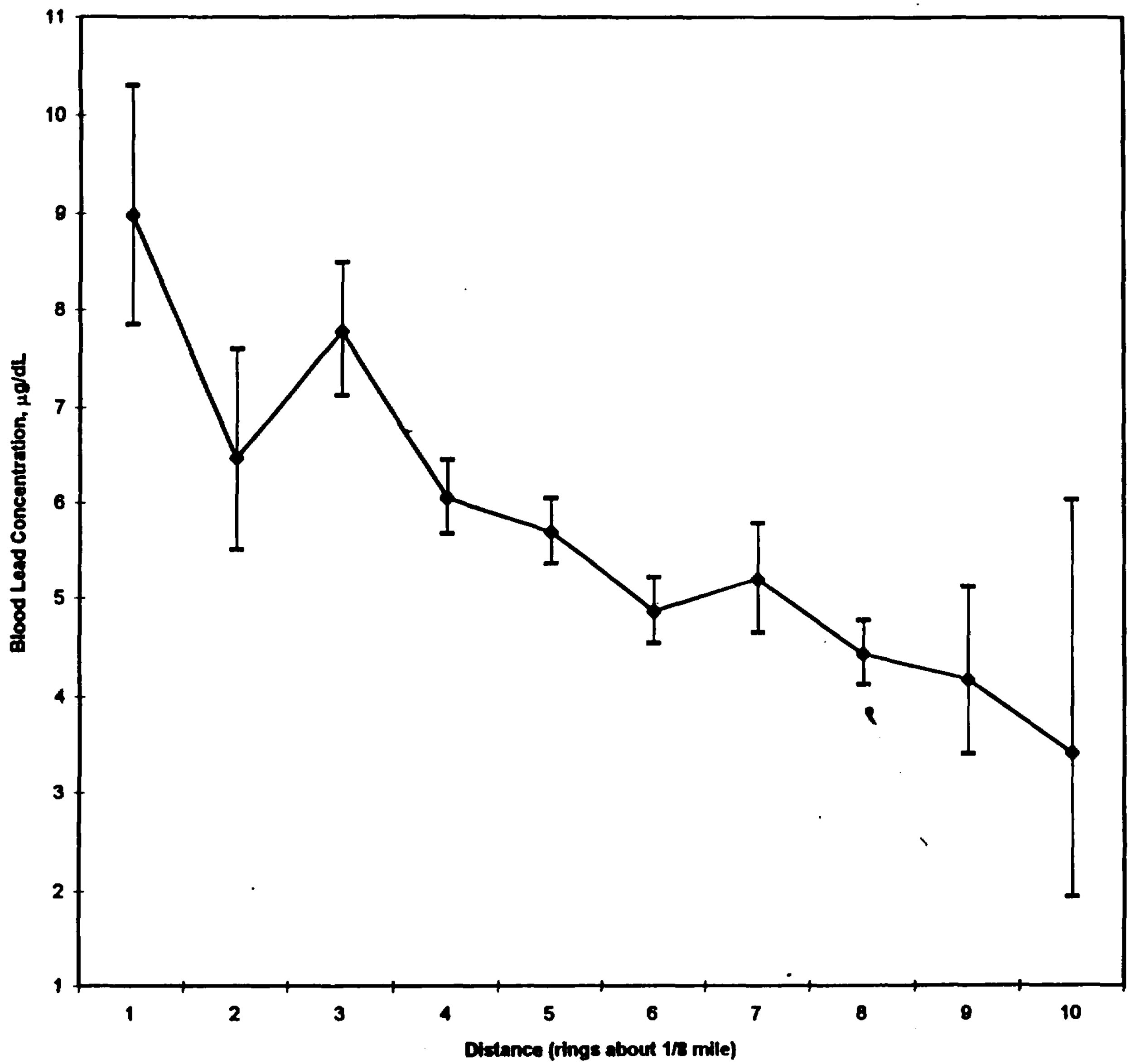
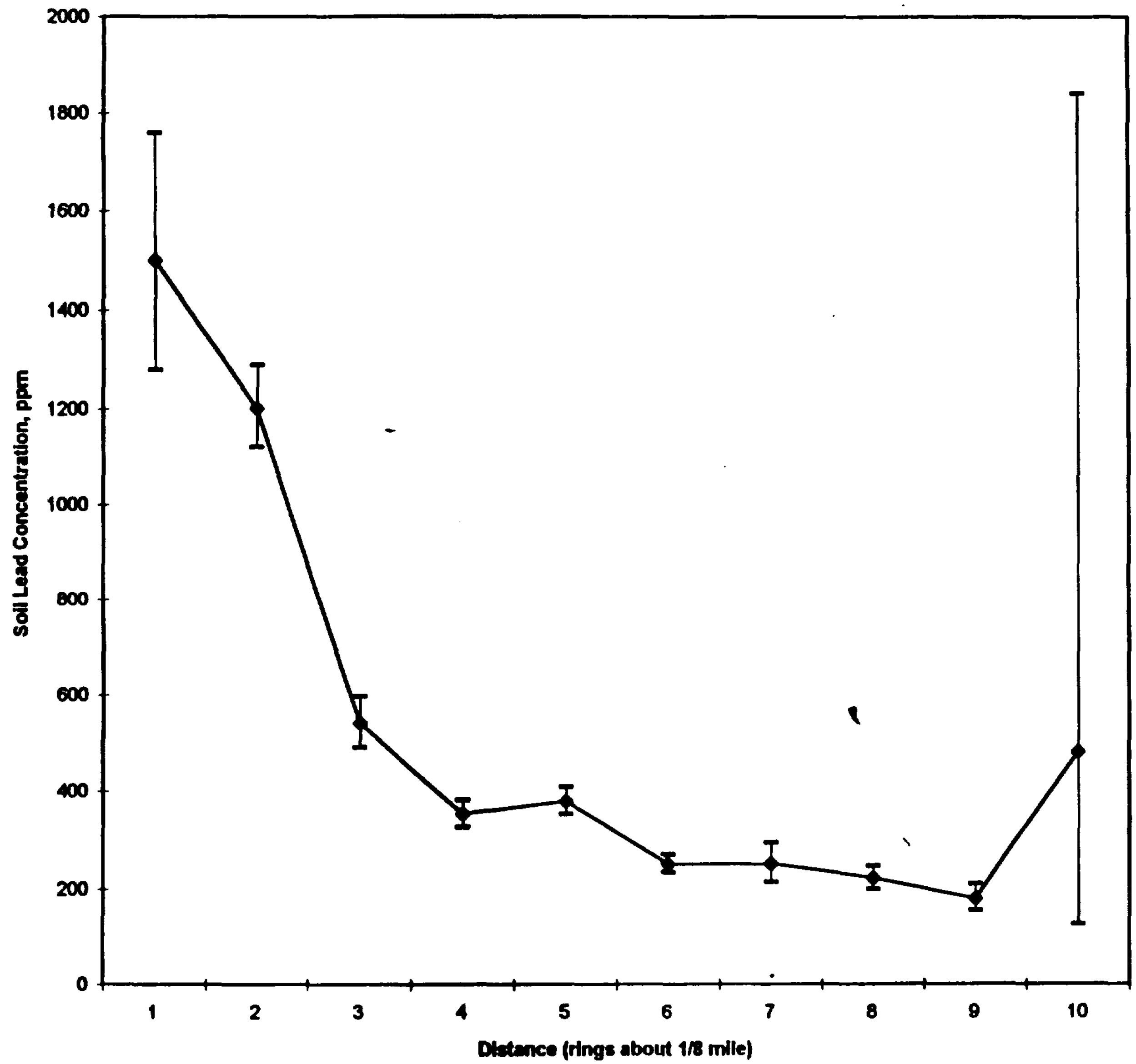


Figure 5. Geometric mean soil lead concentration in residences of Madison County children decreases with increasing distance from the NL/Taracorp lead smelter. Bars show one geometric or relative standard error of geometric mean.



decreases with increasing distance [illegible]m the NL/Taracorp lead smelter. Bars show one geometric or relative standard error of geom[illegible]c mean.

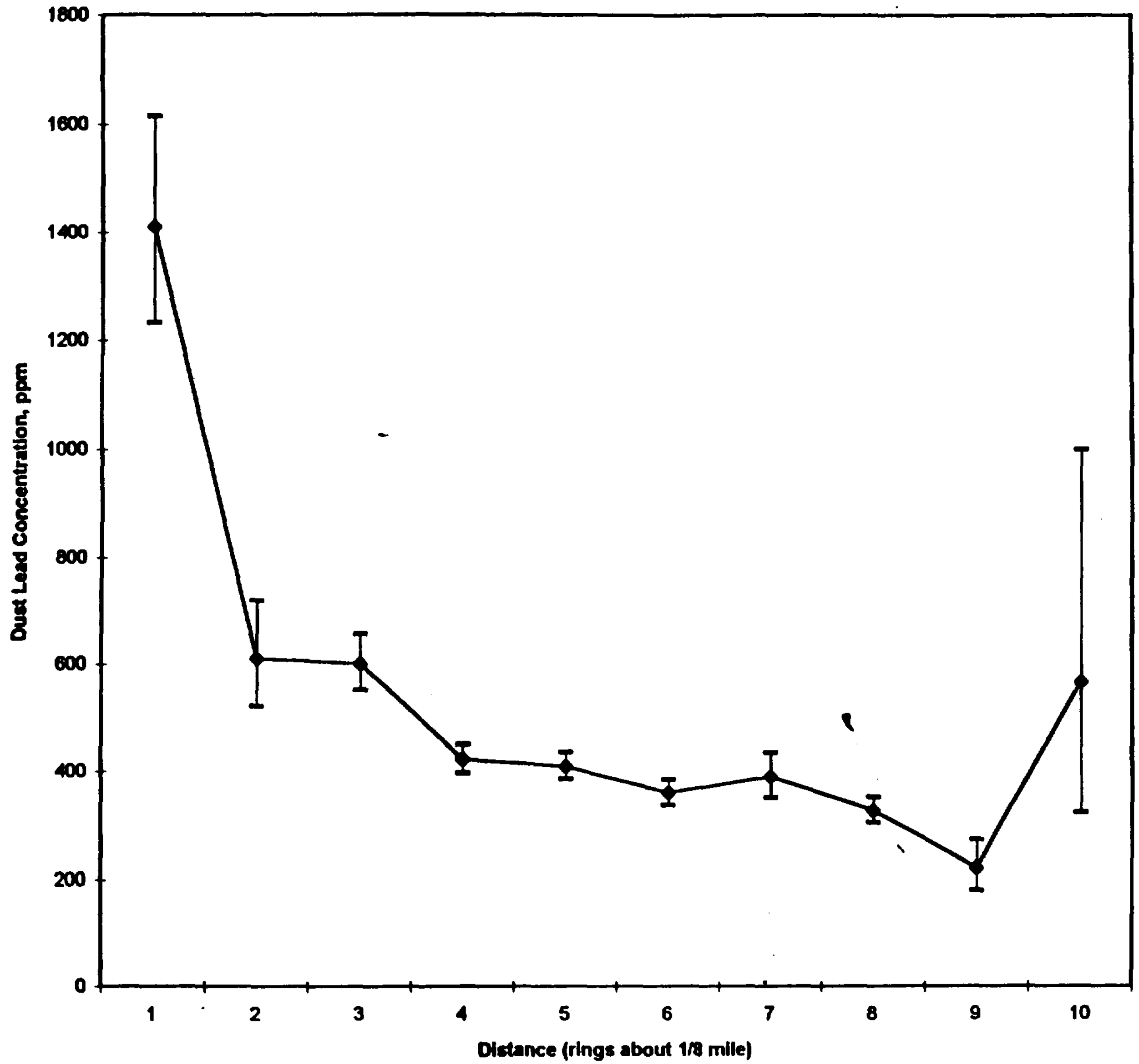


Figure 7. Geometric mean dust lead loading in residences of Madison County children decreases with increasing distance from the NL/Taracorp lead smelter. Bars show one geometric or relative standard error of geometric mean.

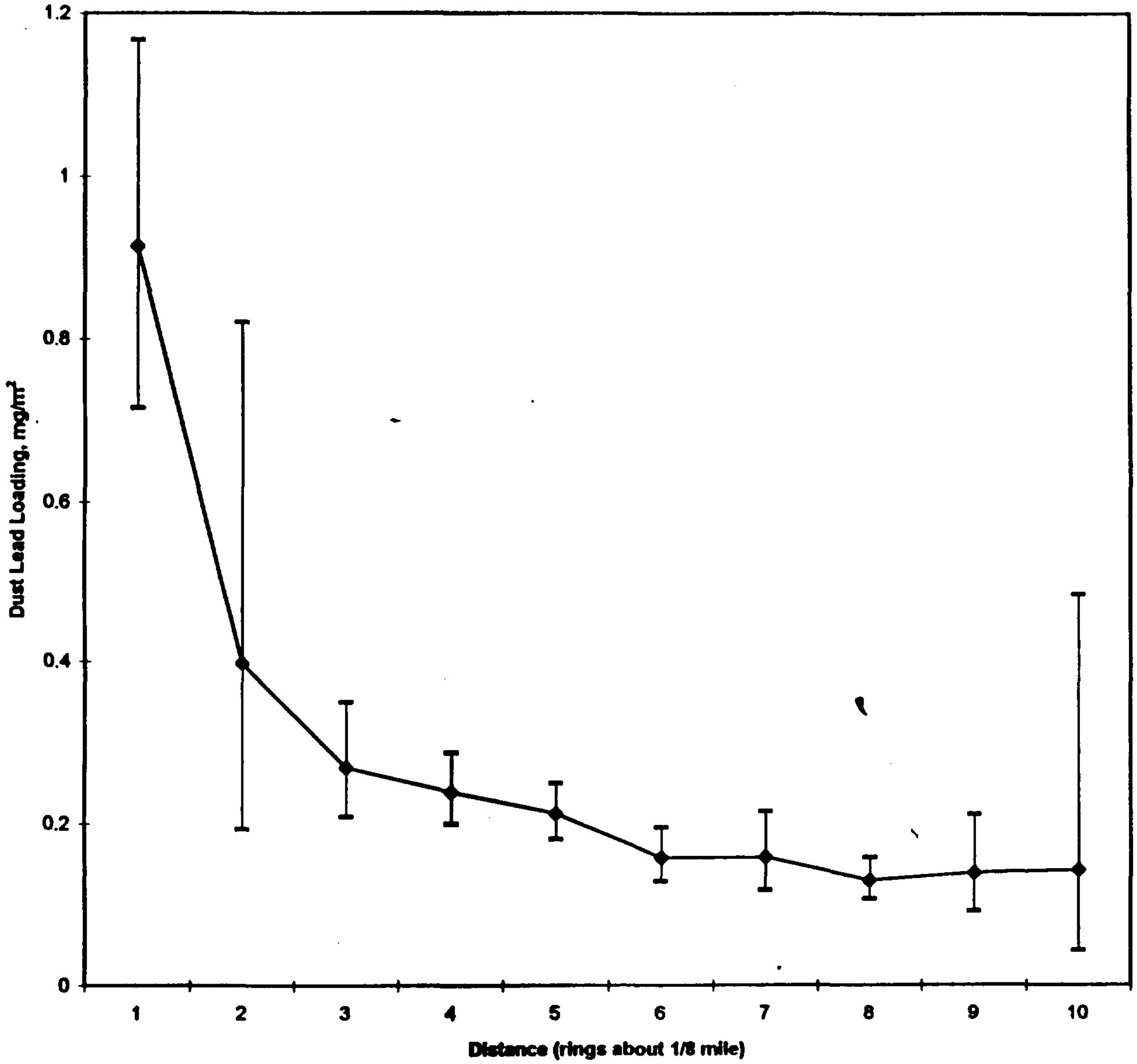


Figure 8. Mean interior lead paint hazard index (product of interior lead paint loading and paint condition) in residences of Madison County children decreases slightly with increasing distance from the NL/Taracorp lead smelter. Bars show one standard error of mean.

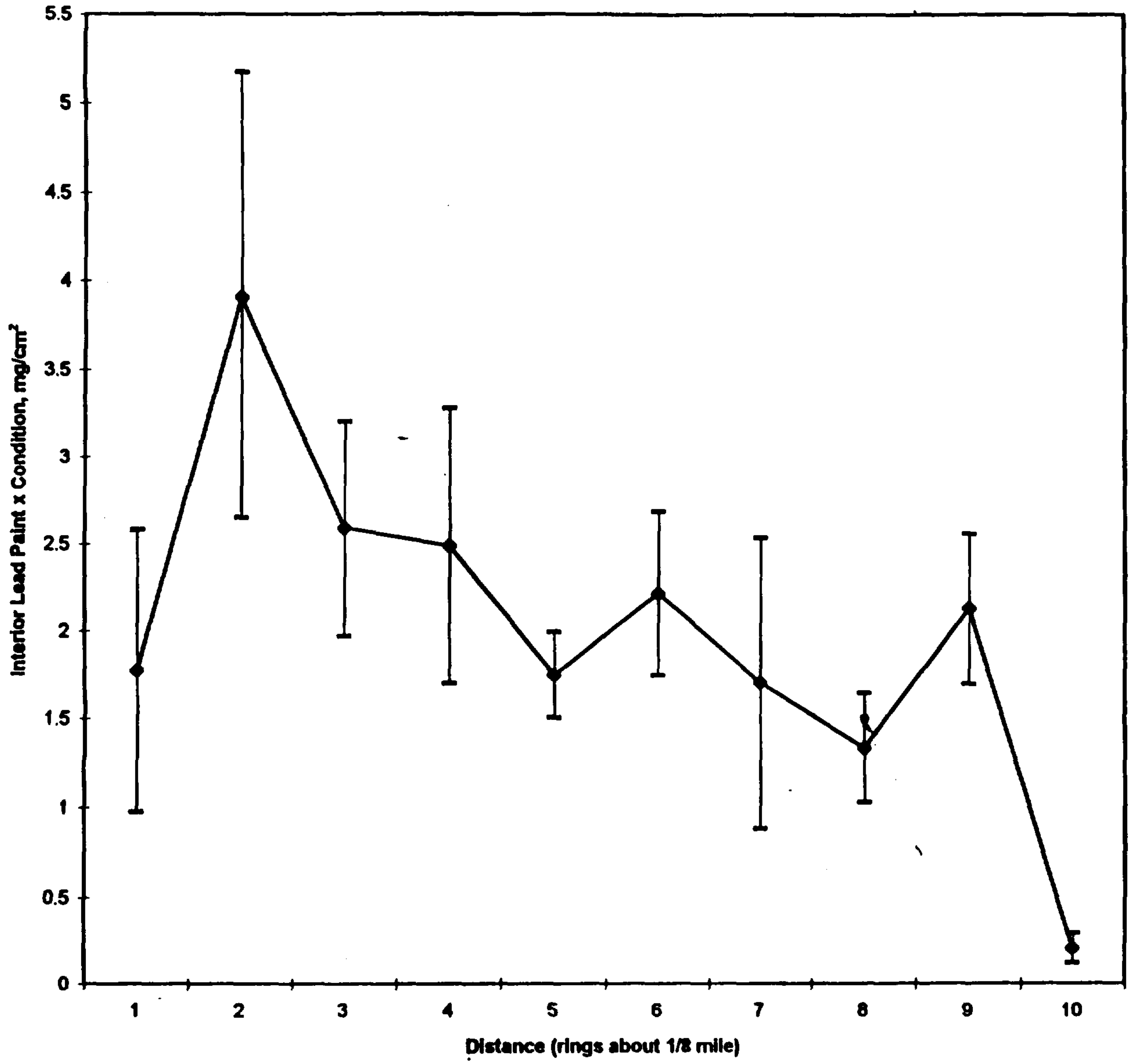


Figure 9. Mean exterior lead paint hazard index (product of exterior lead paint loading and paint condition) in residences of Madison County children shows little relationship with increasing distance from the NL/Taracorp lead smelter. Bars show one standard error of mean.

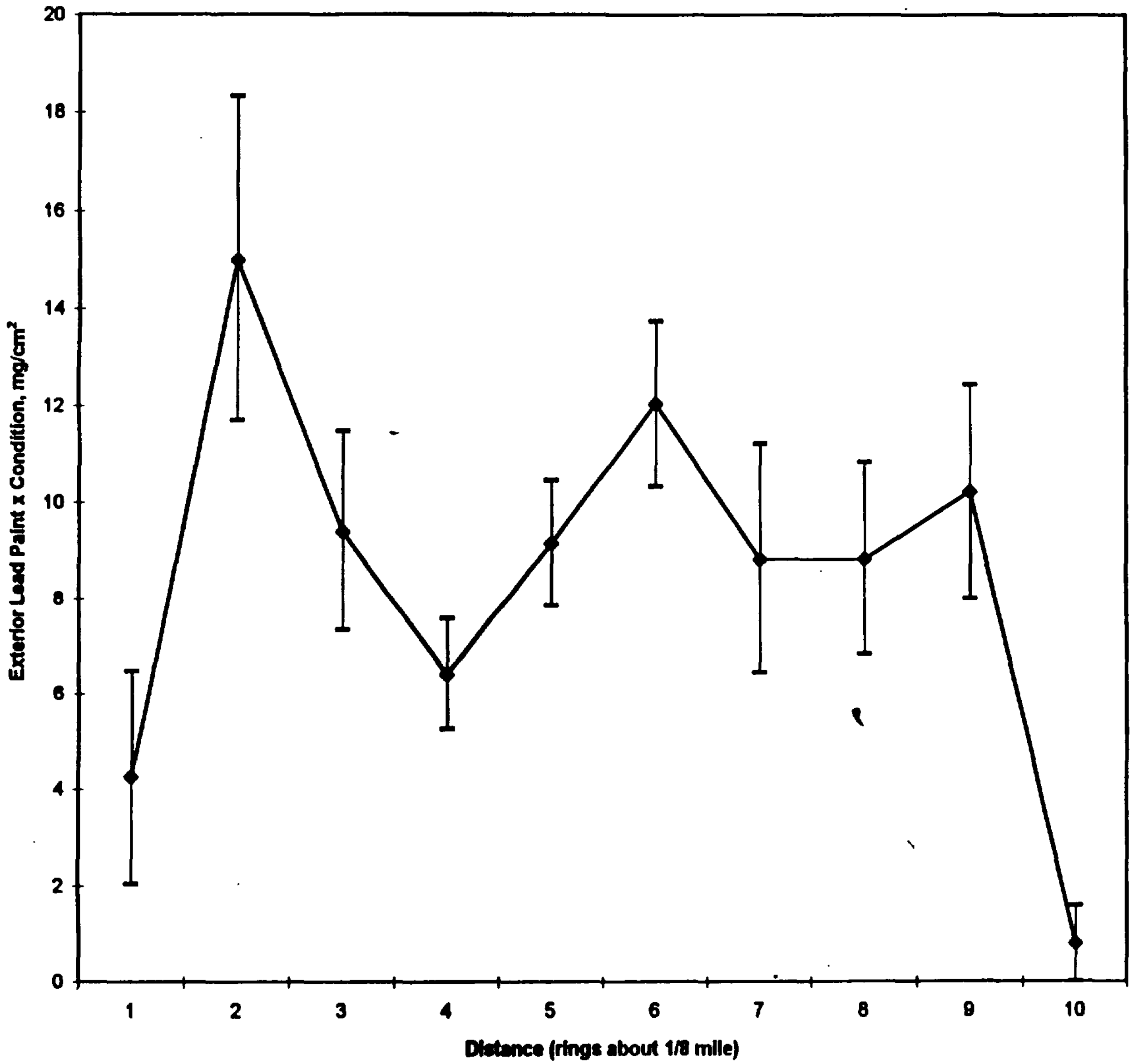
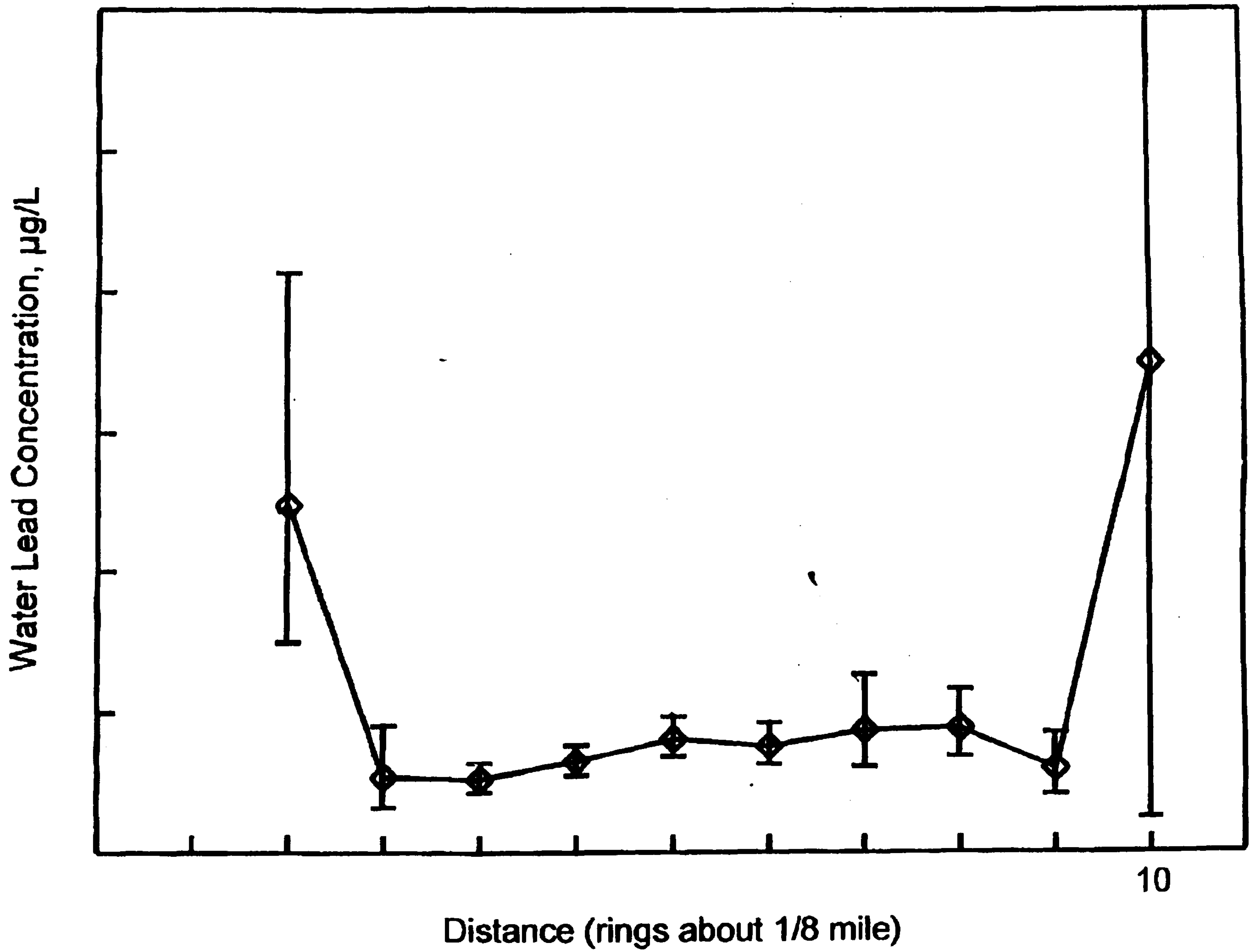


Figure 10. Geometric mean wate ncentration in residences of Madison County children shows little relation to increasing dista... from the NL/Taracorp lead smelter, beyond ring 1. Bars show one geometric or relative standard error of geometric mean.



... residences of Madison County children
shows a very slight decrease with increasing distance from the NL/Taracorp lead smelter. Bars show one geometric or relative standard error of geometric mean.

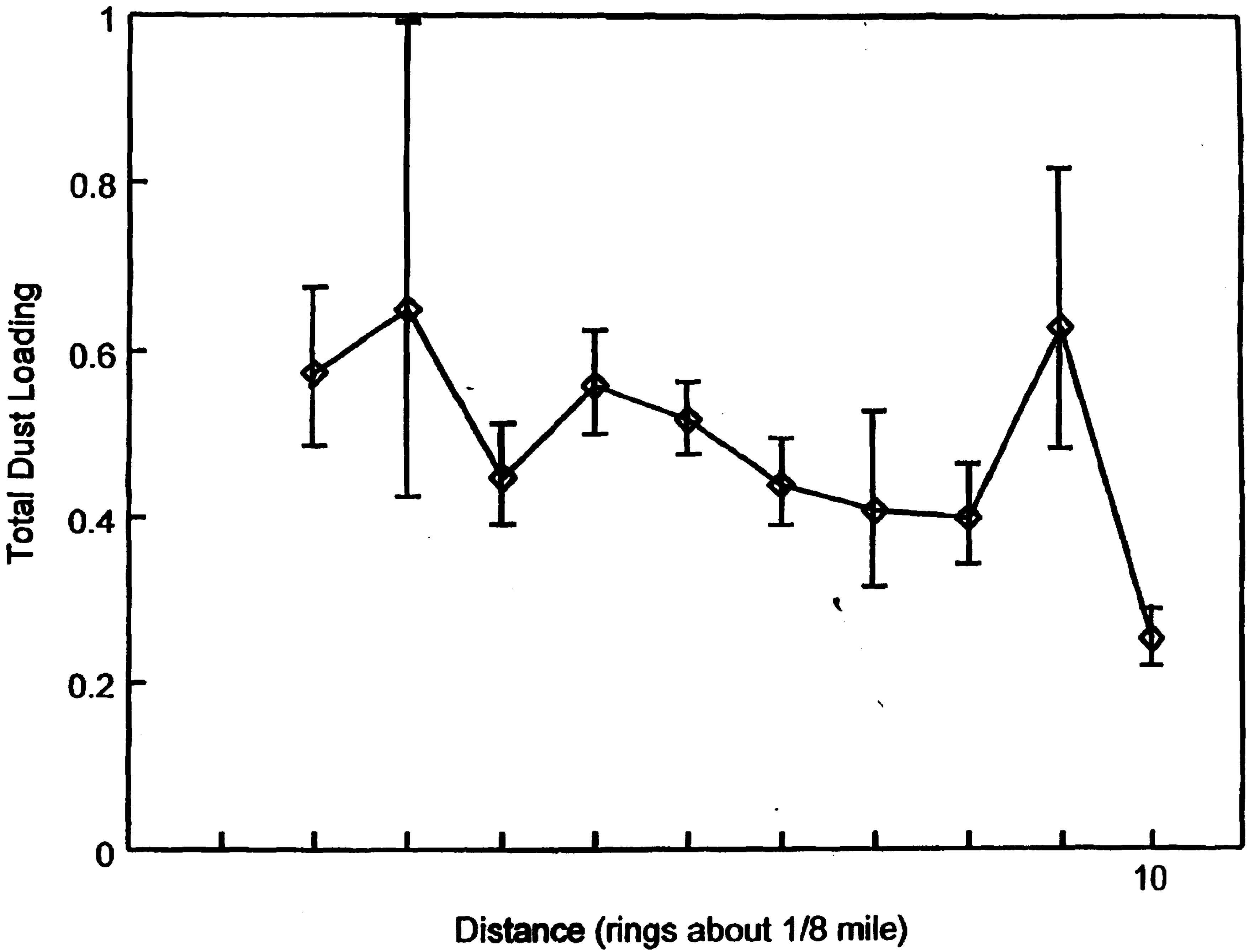


Figure 12. Mean exterior building con[illegible]ion of residences of Madison County children decreases with increasing distance from the NL[illegible].corp lead smelter. Bars show one standard error of mean.

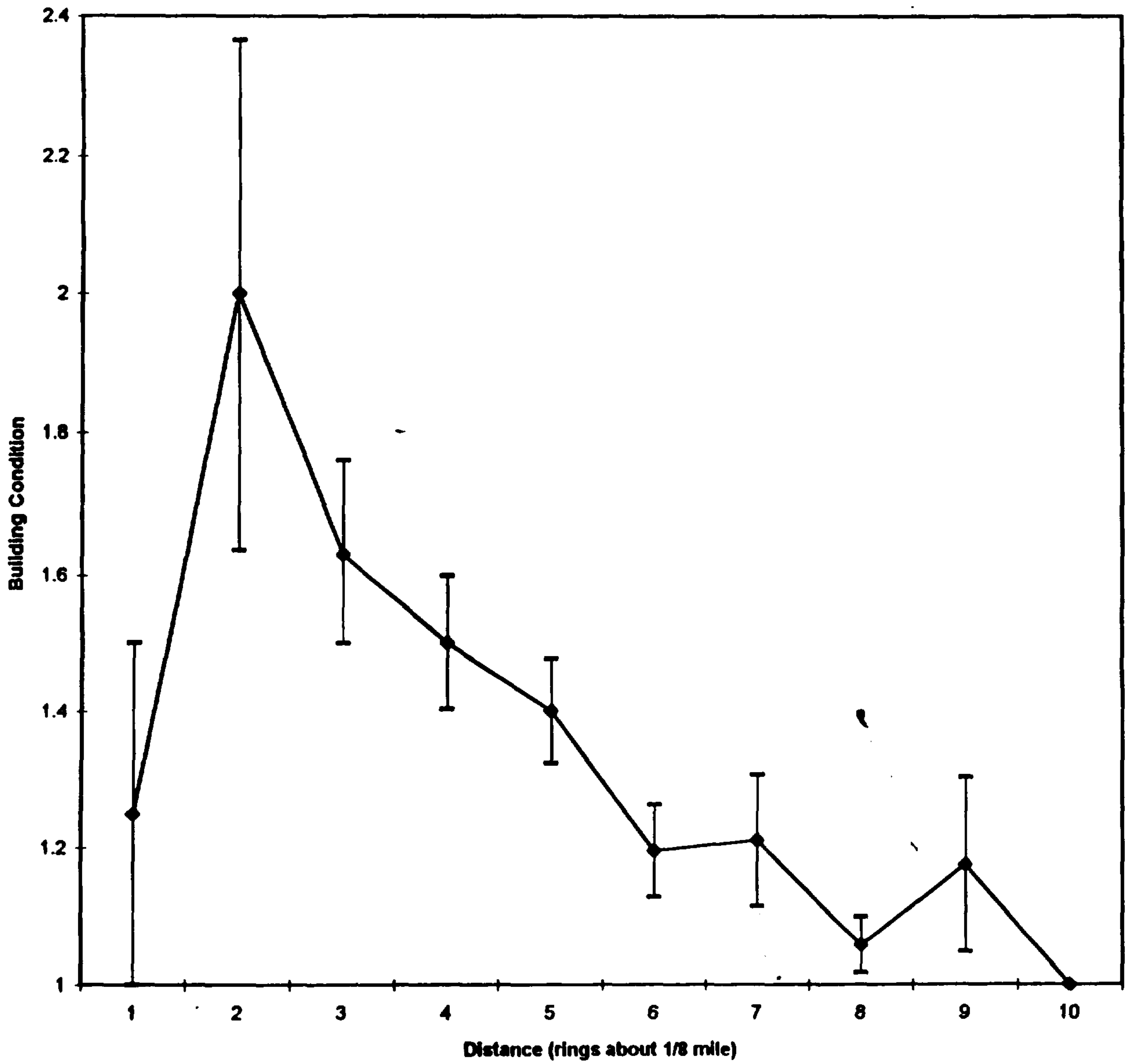


Figure 13. Mean years of education of parents of Madison County children increases with increasing distance from the NL/Taracorp lead smelter. Bars show one standard error of mean.

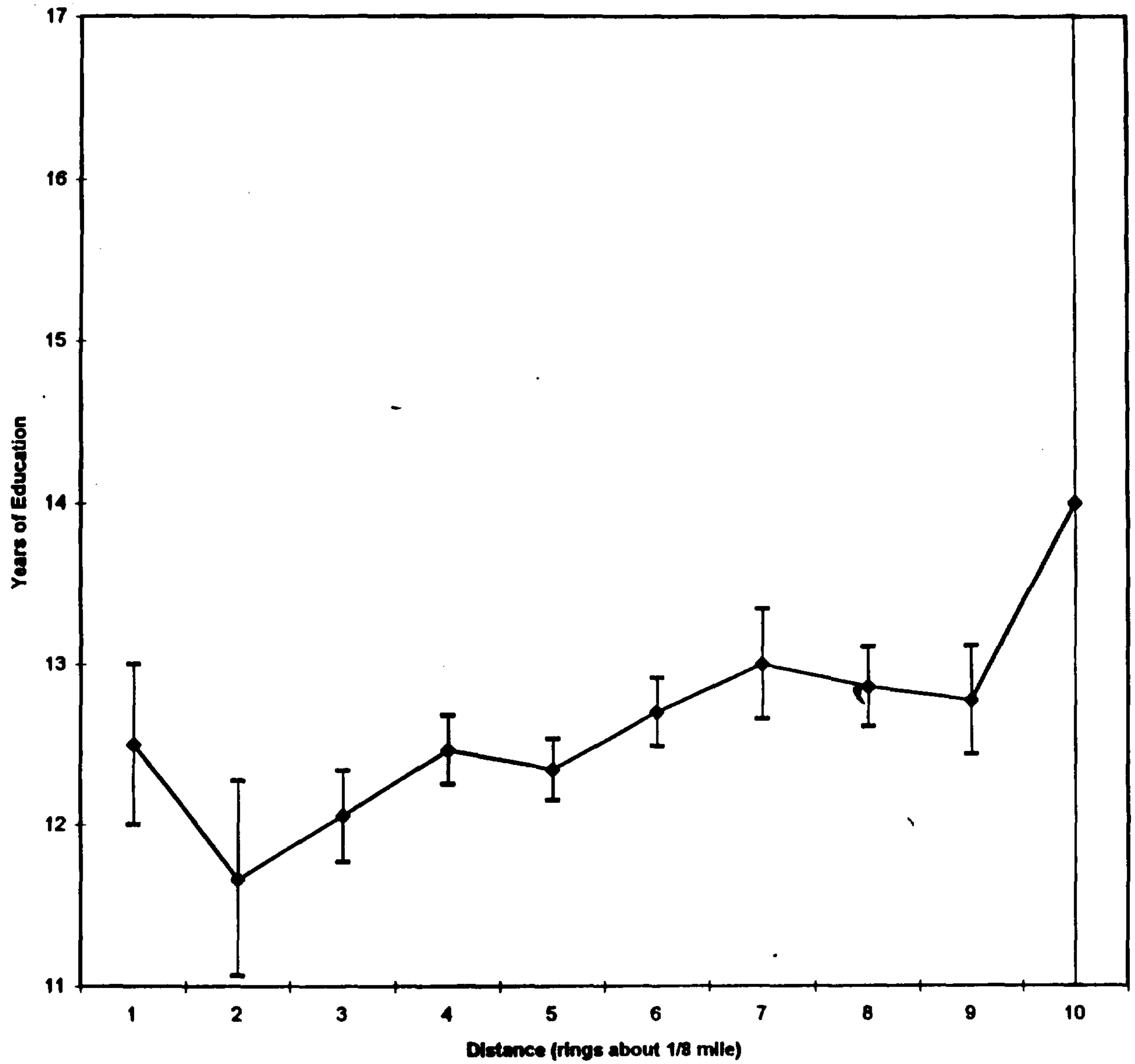


Figure 14. Percent of Madison County children in rental housing decreases with increasing distance from the NL/Taracorp lead ter beyond ring 6. Bars show one standard error of percentage estimate.

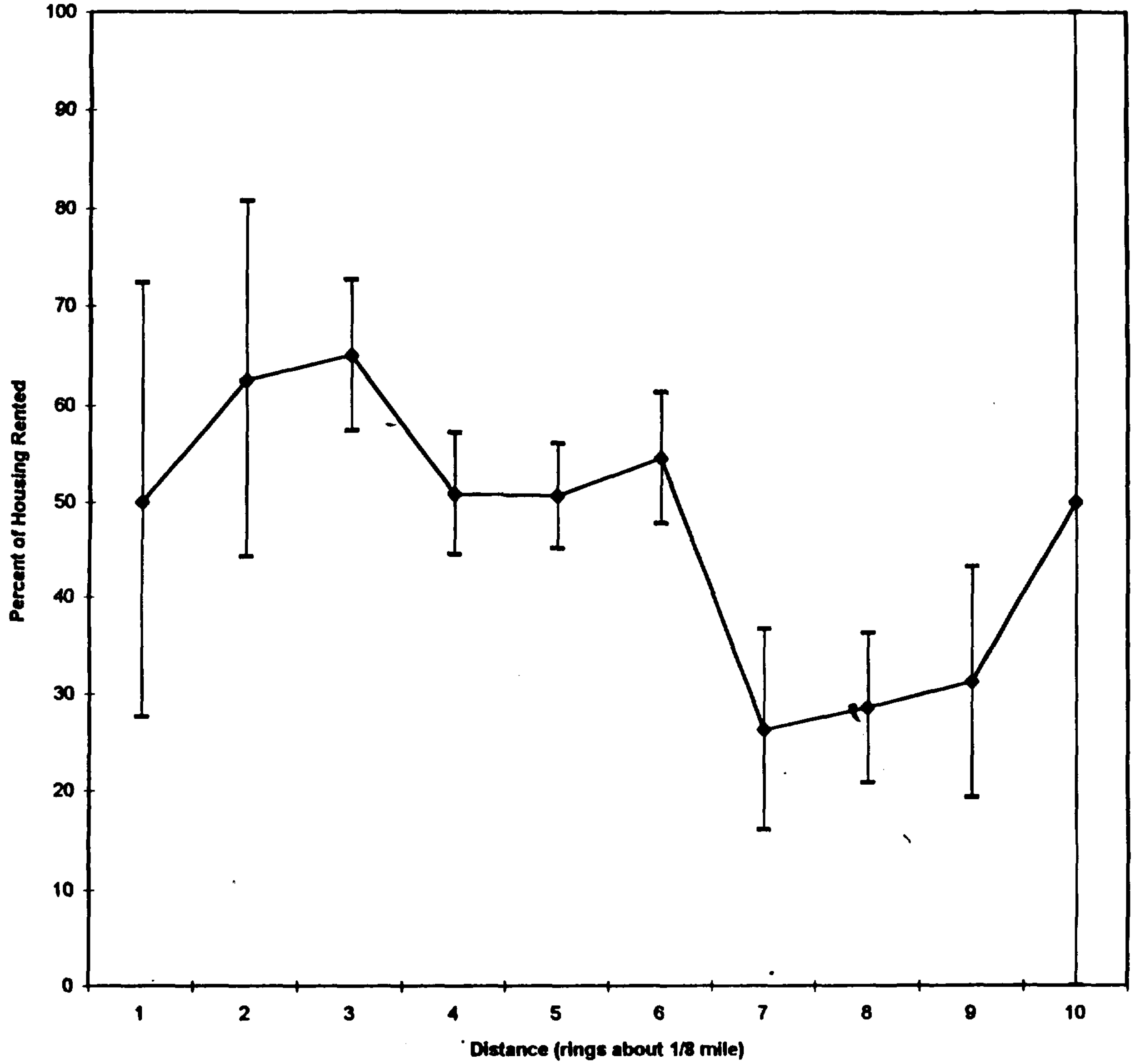


Figure 15. Percent of non-white Madison County children increases with increasing distance from the NL/Taracorp lead smelter. Bars show one standard error of percentage estimate.

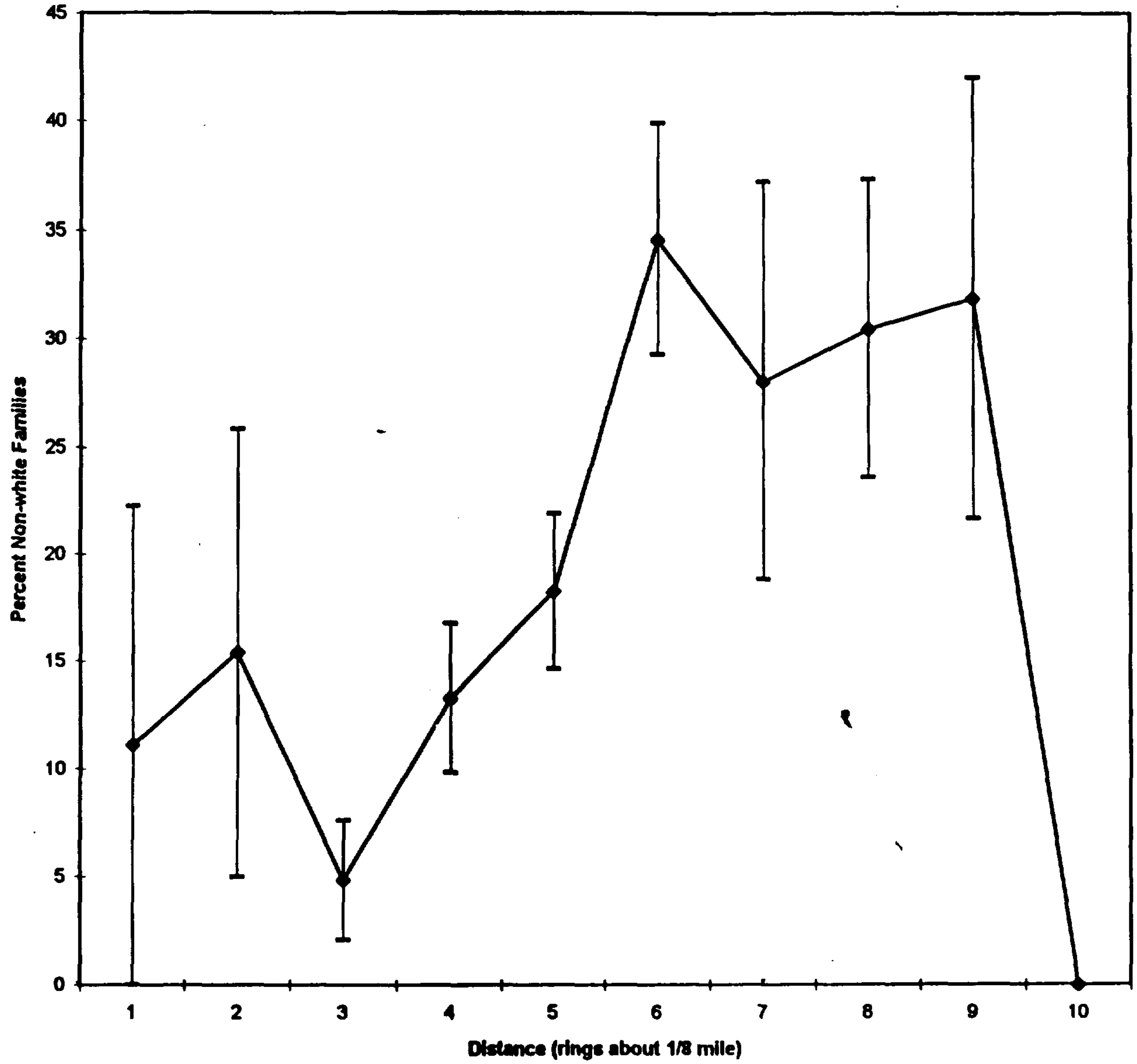
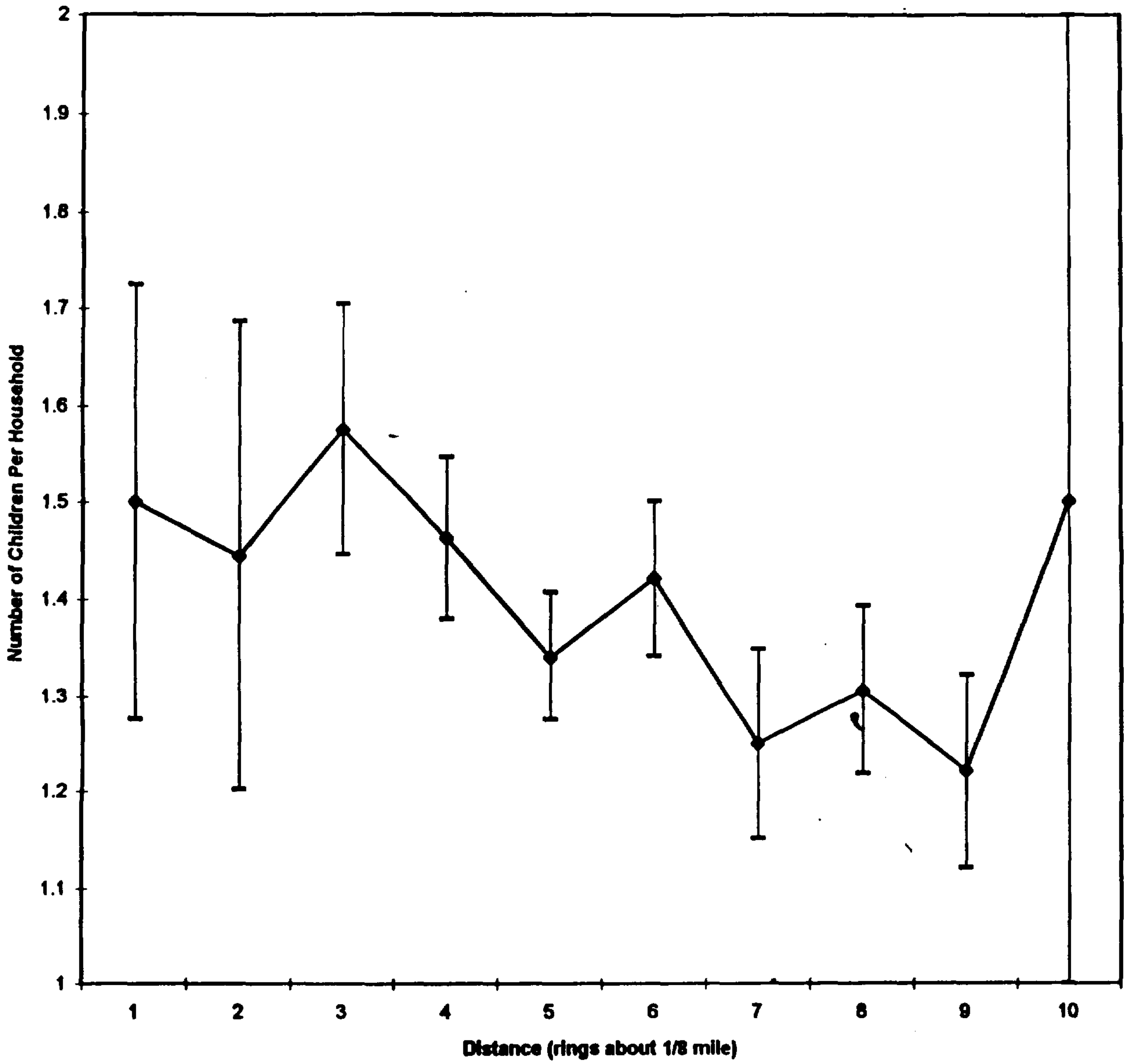


Figure 16. Mean number of preschool children per household in households of Madison County children decreases with increasing [illegible]nce from the NL/Taracorp lead smelter. Bars show one standard error of mean.



with increasing distance from the NL/Taracorp lead smelter. Bars show one standard error of percentage estimate.

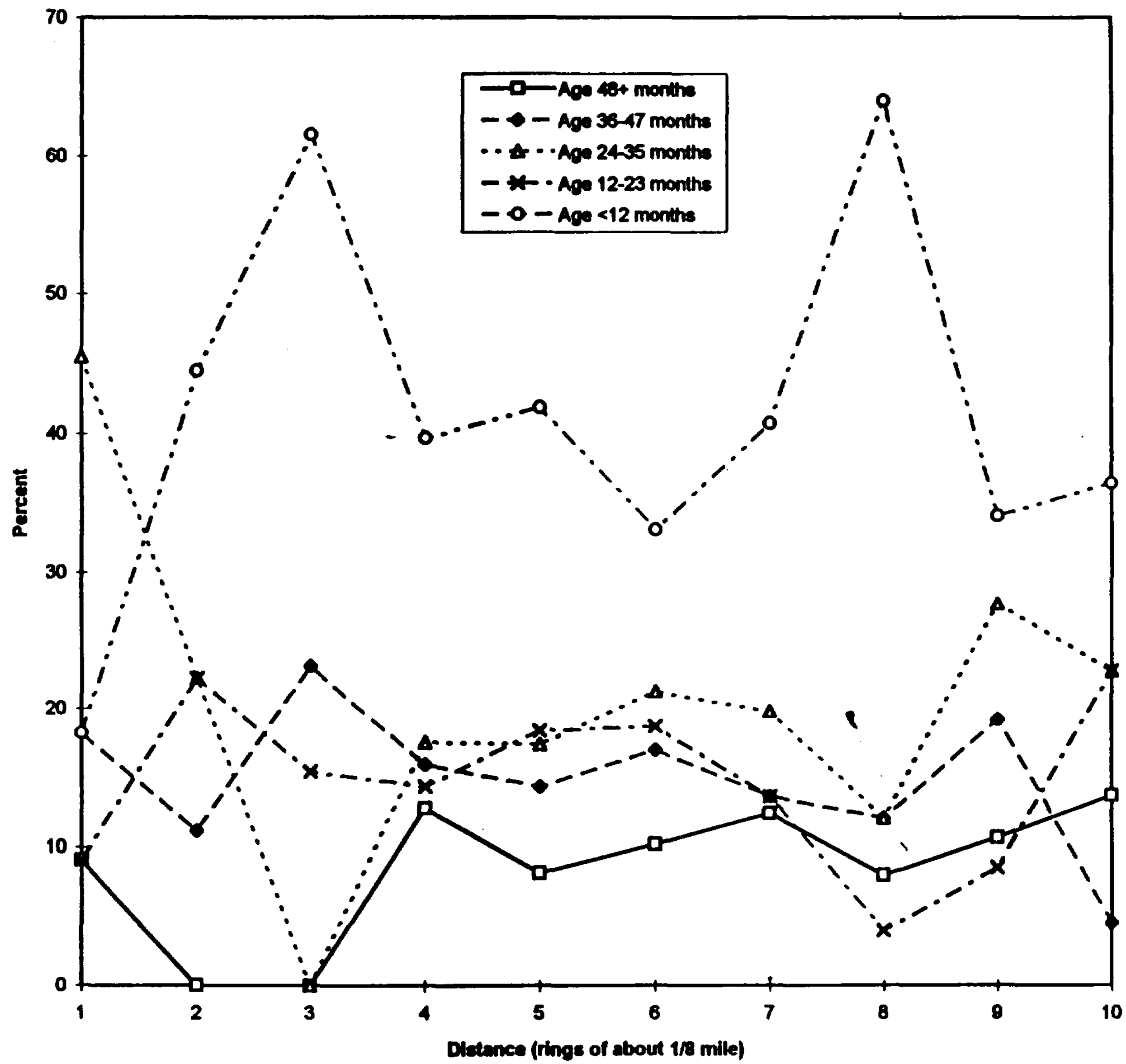
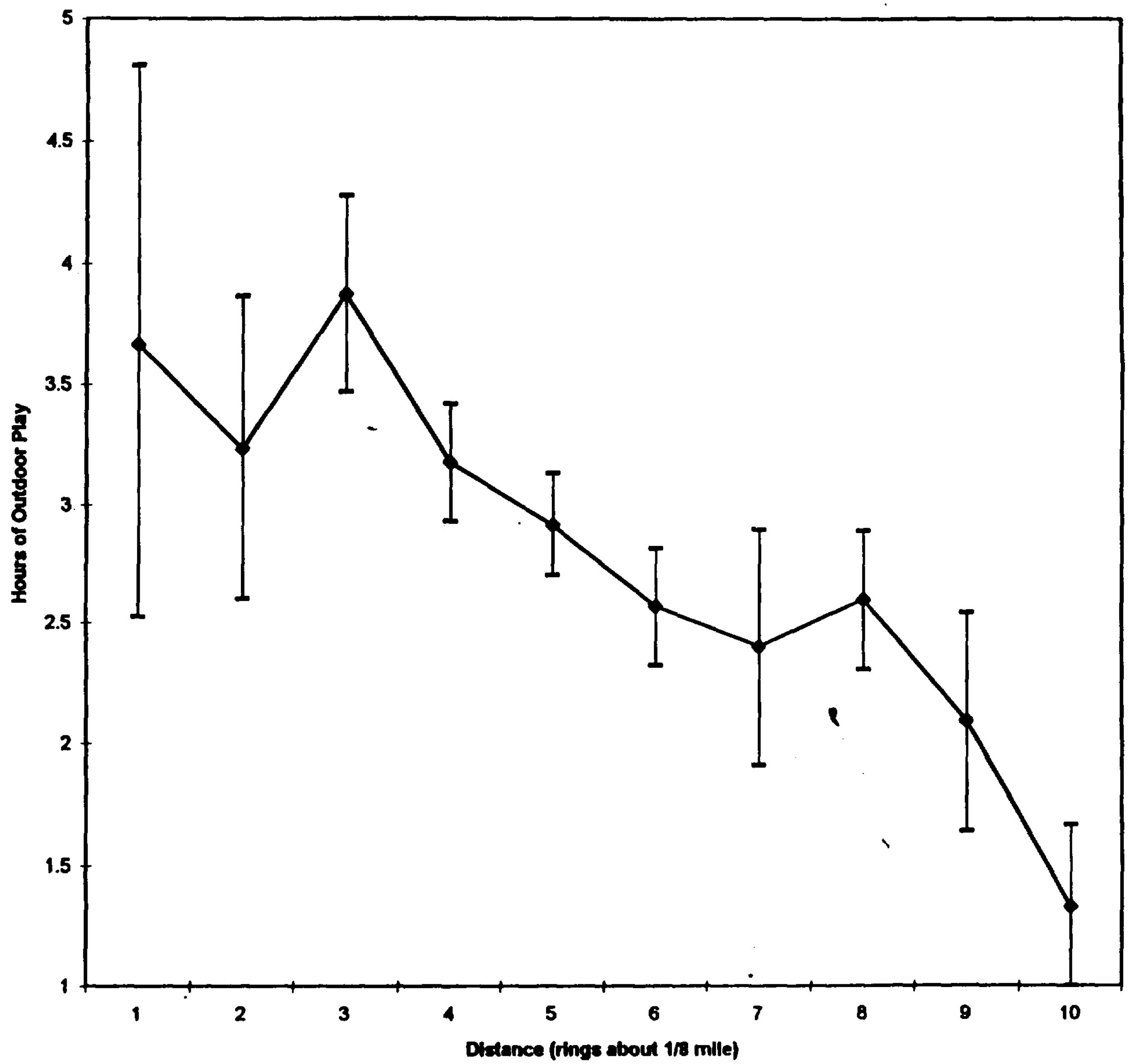


Figure 18. Mean hours of outdoo[illegible]y per day of Madison County children decreases with increasing distance from the NL/T[illegible]corp lead smelter. Bars show one standard error of mean.



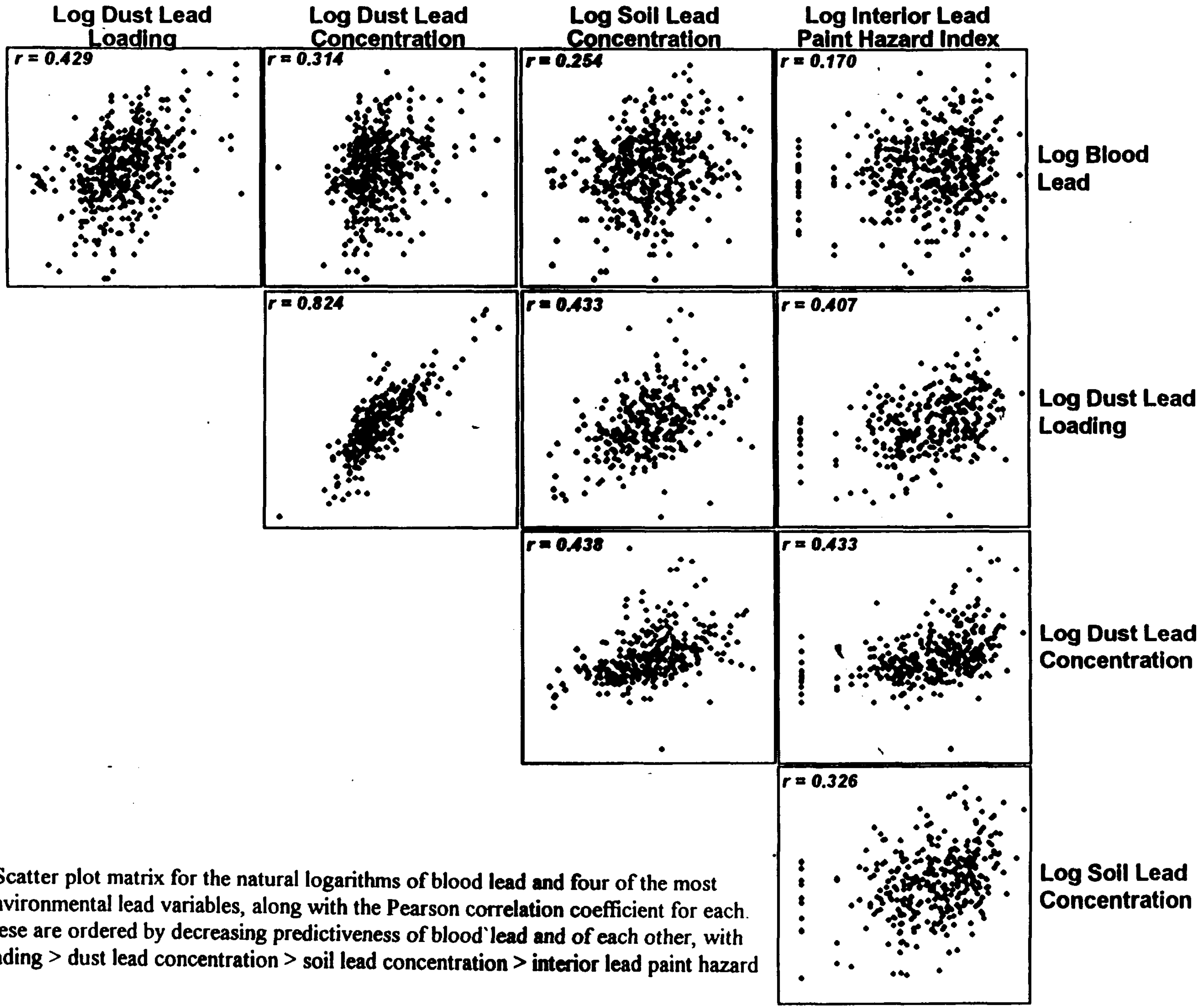


Figure 19. Scatter plot matrix for the natural logarithms of blood lead and four of the most important environmental lead variables, along with the Pearson correlation coefficient for each. Note that these are ordered by decreasing predictiveness of blood lead and of each other, with dust lead loading > dust lead concentration > soil lead concentration > interior lead paint hazard index.

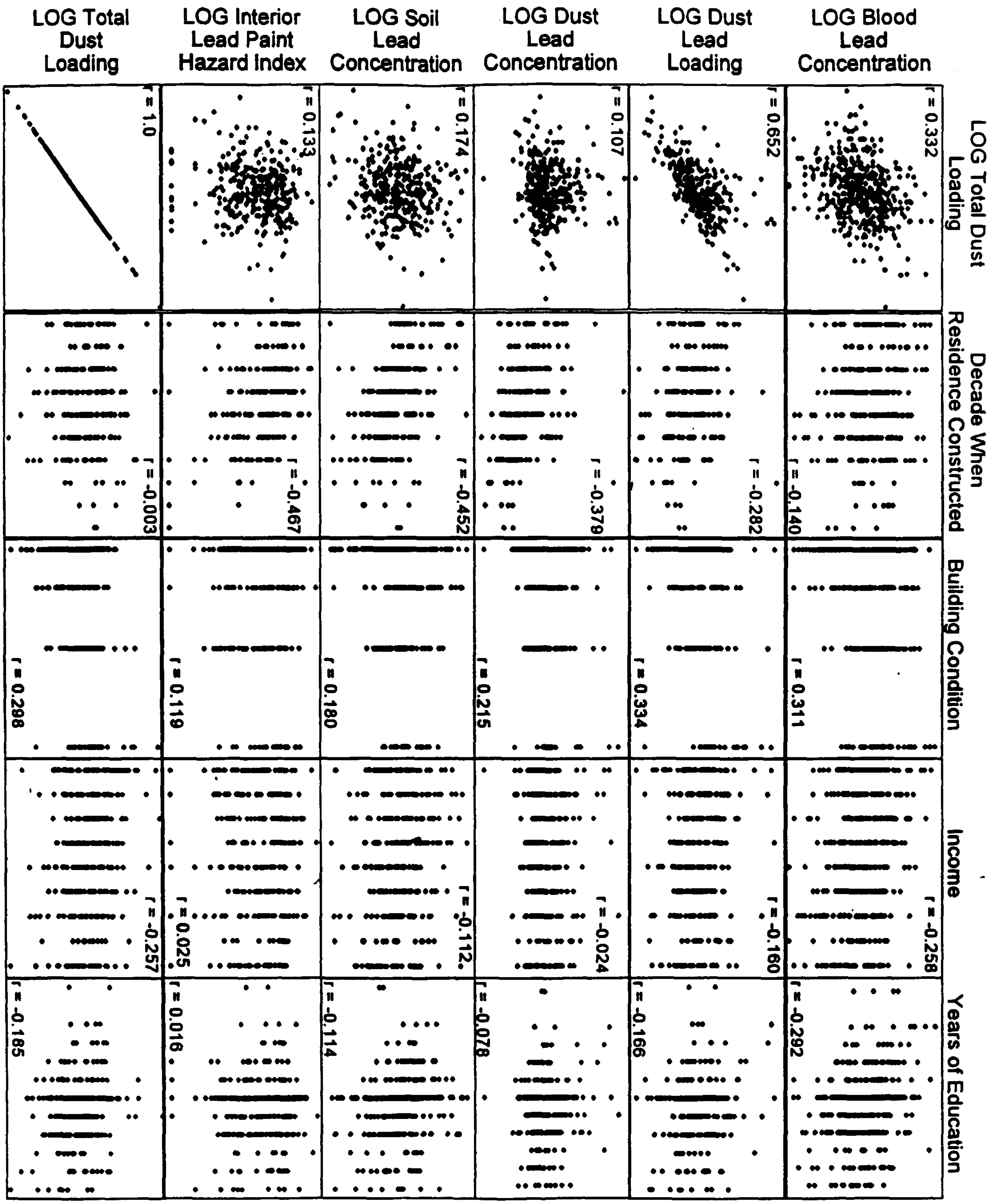


Figure 20. Scatter plot matrix for cross-correlation of the natural logarithms of blood lead, four of the environmental lead variables (dust lead loading, dust lead concentration, soil lead concentration, and interior lead paint hazard index) and total dust loading vs. three environmental factors (total dust loading, housing age, exterior building condition) and two sociodemographic

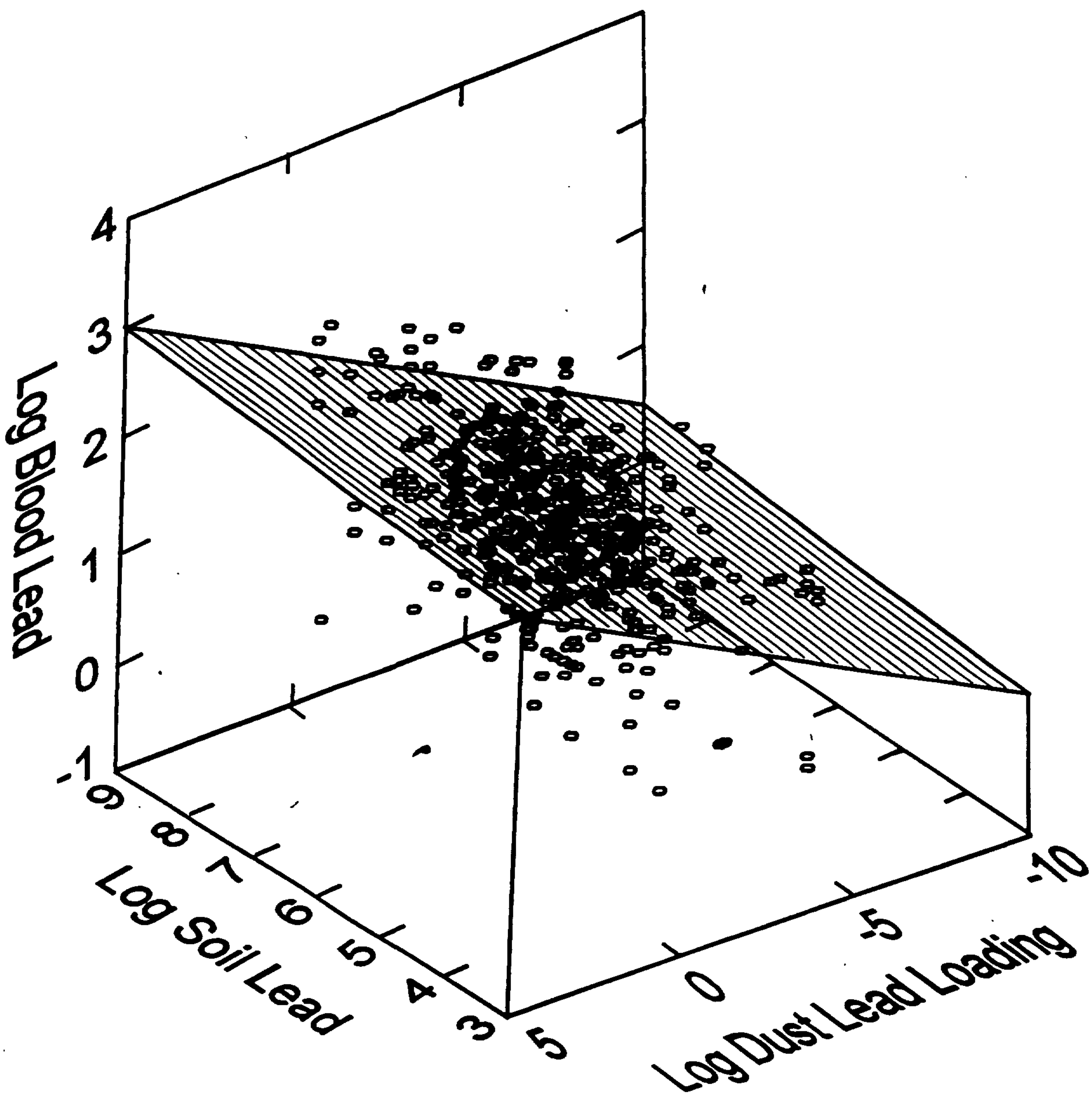


Figure 21. Scatter plot for natural logarithm of blood lead, dust lead loading, and soil lead is shown in a three-dimensional representation. The multiple regression relationship of log(blood lead) on log(dust lead loading) and log(soil lead) is shown as a shaded plane surface. Note that most data points lie close to the plane, and that there is a relatively large effect of dust lead loading. There is also a slight effect of soil lead on blod lead, shown as a small positive slant of the multiple regression surface projected on the log(blood lead) vs. log(soil lead) plane.

Figure 22. Percentage of households in which the estimated contribution of soil lead to household dust exceeds the estimated contribution of deteriorating lead-based paint decreases with increasing distance from the NL/Taracorp site, but still exceeds 50 percent up to ring 8.

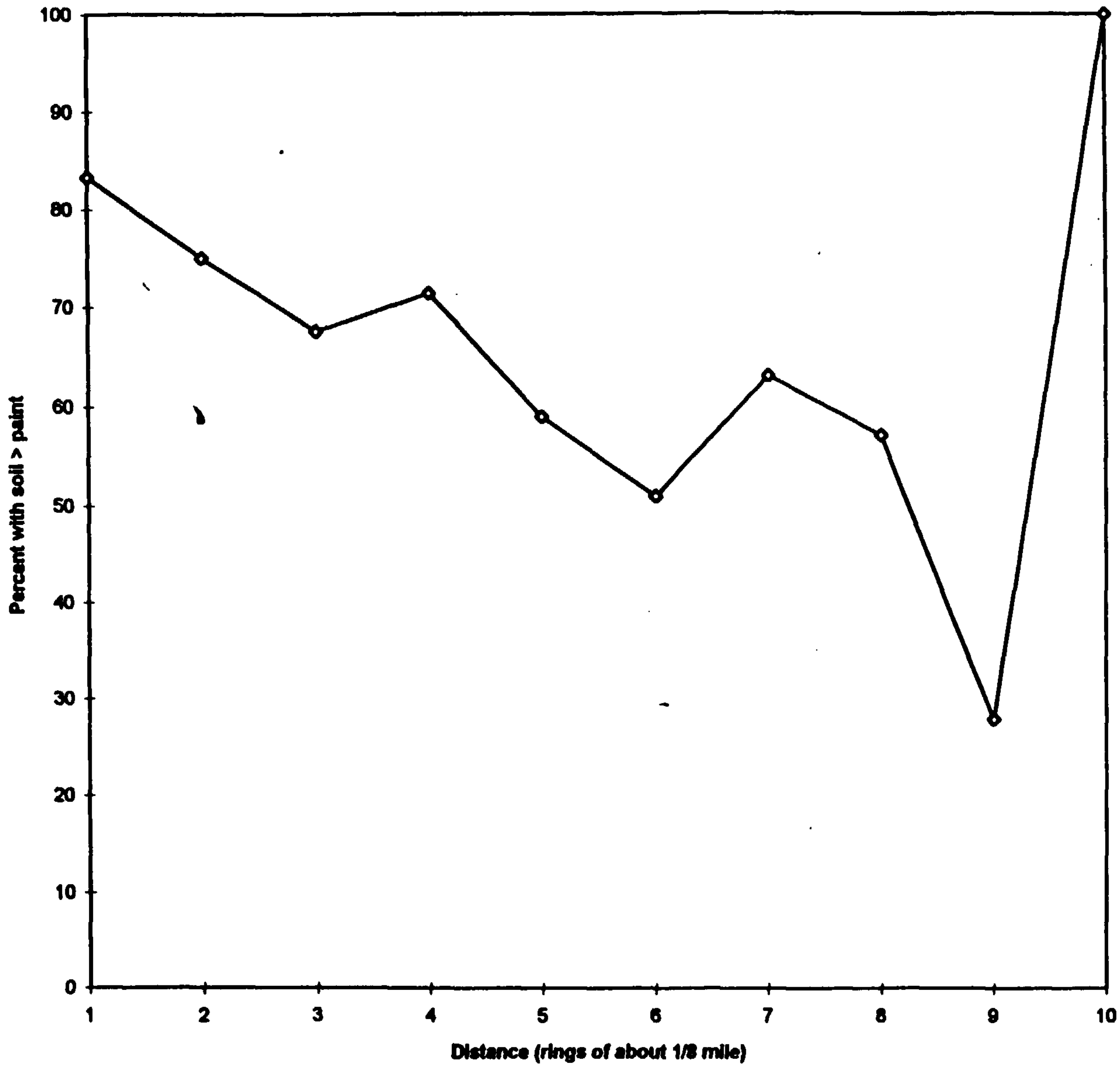


Figure 23. Structural equation model for environmental lead in the Madison County study, using Model 1 (linear relationship among log-transformed variables) as described in Section 6. Dust lead loading is shown as dust lead concentration modified by total dust loading. The two-tailed P-value or statistical significance of each pathway coefficient in the model is shown in the Figure, and the pathway regression coefficients are shown in Table 14. P-values less than 0.05 suggest that the association is unlikely to be due to chance.

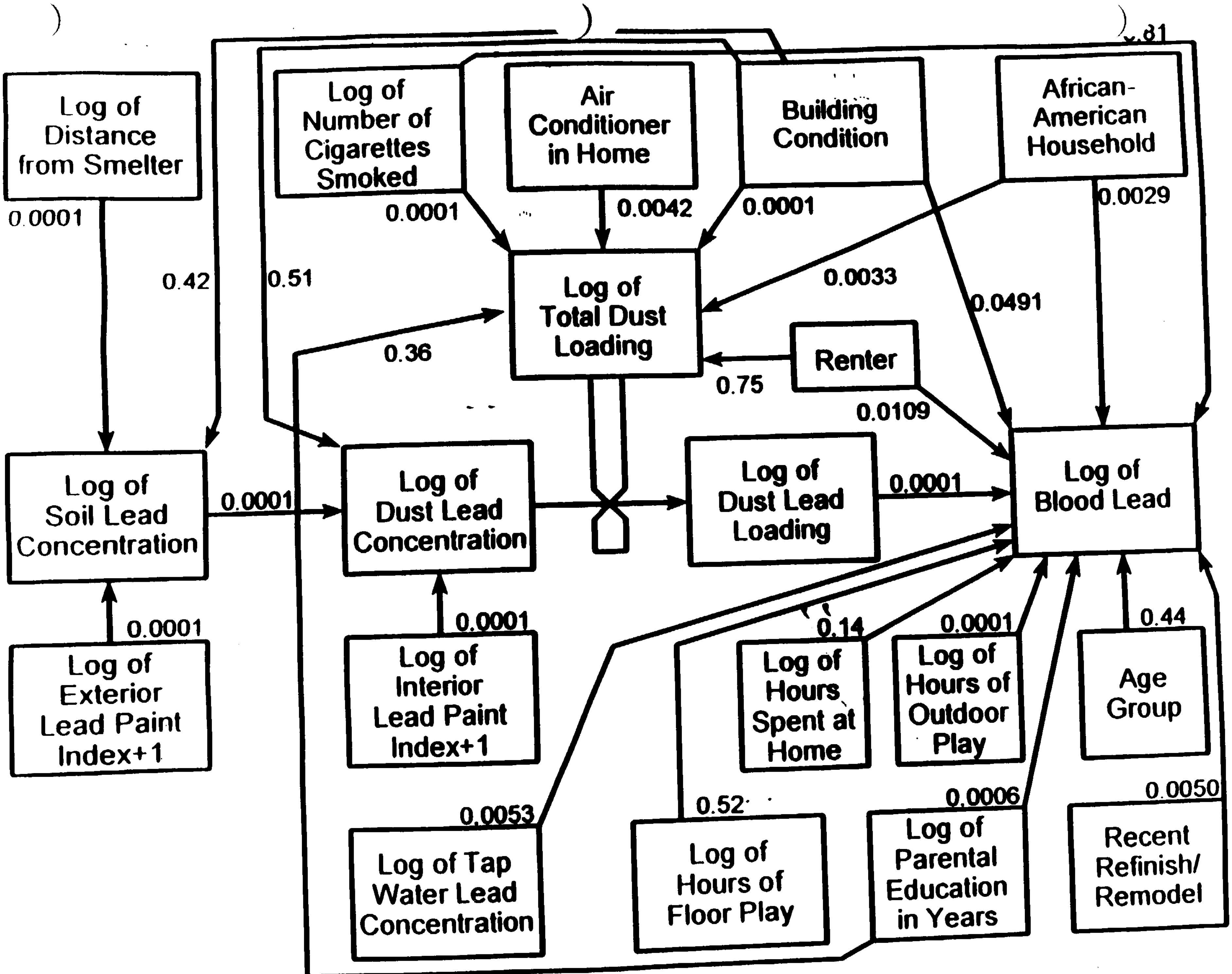

Log of Distance from Smelter
0.0001
0.42
Log of Number of Cigarettes Smoked
0.0001
Air Conditioner in Home
0.0042
Building Condition
0.0001
African-American Household
0.0029
.81
0.51
Log of Total Dust Loading
0.0033
0.0491
0.36
Renter
0.75
0.0109
Log of Soil Lead Concentration
0.0001
Log of Dust Lead Concentration
Log of Dust Lead Loading
0.0001
Log of Blood Lead
0.0001
Log of Exterior Lead Paint Index+1
0.0001
Log of Interior Lead Paint Index+1
0.14
Log of Hours Spent at Home
0.0001
Log of Hours of Outdoor Play
0.44
Age Group
0.0053
Log of Tap Water Lead Concentration
0.52
Log of Hours of Floor Play
0.0006
Log of Parental Education in Years
0.0050
Recent Refinish/ Remodel

Figure 23

Figure 24. Structural equation model for environmental lead in the Madison County study, using Model 2 (linear relationship among non-transformed variables) as described in Section 6. Dust lead loading is shown as dust lead concentration modified by total dust loading. The two-tailed P-value or statistical significance of each pathway coefficient in the model is shown in the Figure, and the pathway regression coefficients are shown in Table 15. P-values less than 0.05 suggest that the association is unlikely to be due to chance.

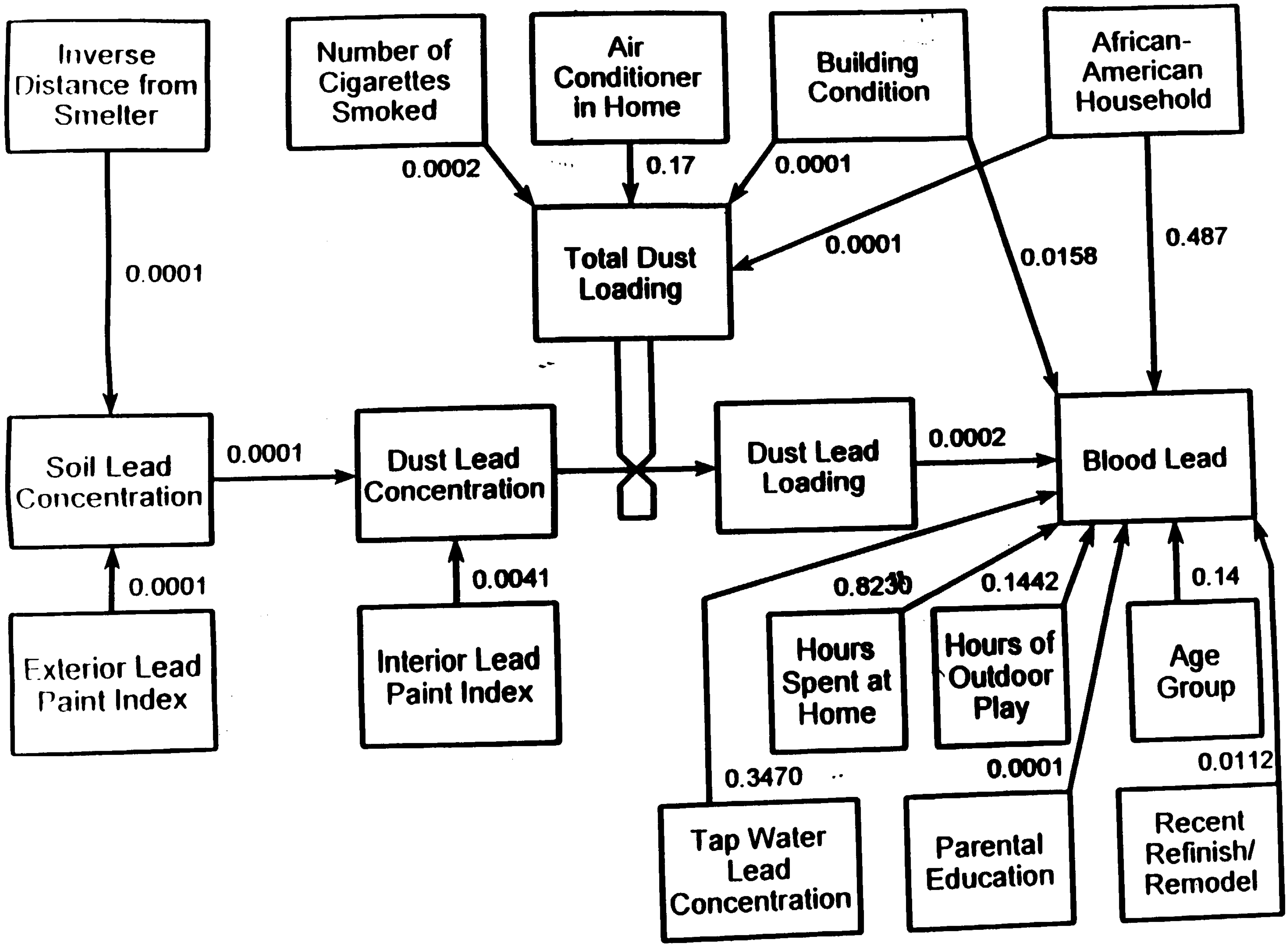
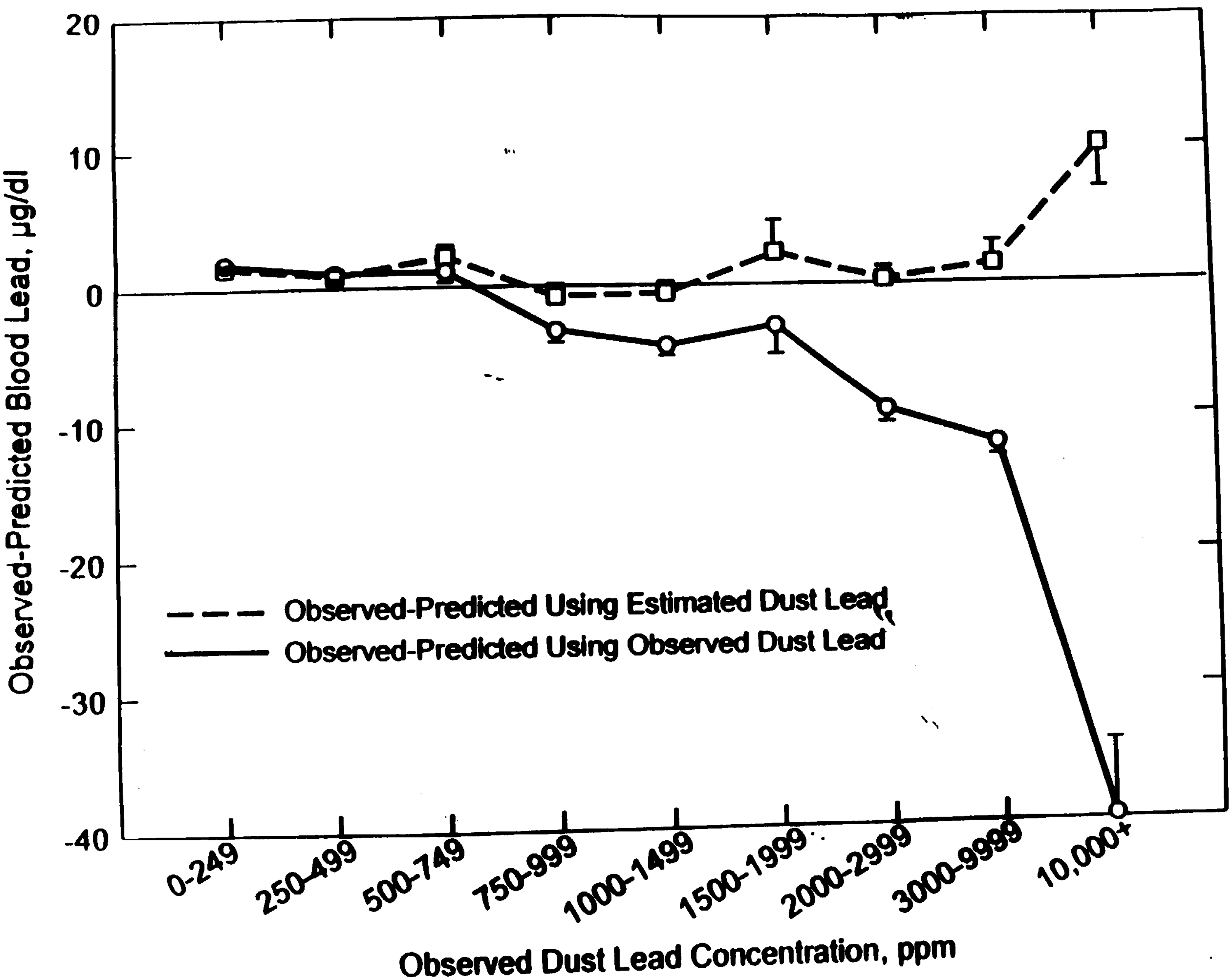

Inverse Distance from Smelter
0.0001
Number of Cigarettes Smoked
0.0002
Air Conditioner in Home
0.17
Building Condition
0.0001
African-American Household
0.0001
0.0158
0.487
Total Dust Loading
Soil Lead Concentration
0.0001
Dust Lead Concentration
Dust Lead Loading
0.0002
Blood Lead
0.0001
0.0041
Exterior Lead Paint Index
Interior Lead Paint Index
0.8230
0.1442
0.14
Hours Spent at Home
Hours of Outdoor Play
Age Group
0.3470
0.0001
0.0112
Tap Water Lead Concentration
Parental Education
Recent Refinish/ Remodel

Figure 24

Figure 25. Mean difference between observed and predicted blood lead concentration for two different sets of input data for the IEUBK Model for lead in children in the Madison County Lead Study. The solid line shows the mean differences when observed dust lead is used; the dashed line shows the mean difference when the input is the standard assumption that dust lead = 10 + 0.70 soil lead. Both models give accurate mean estimates for dust lead less than 750 ppm, whereas the estimated dust lead gives consistently better estimates at higher concentrations.



20
10
0
-10
-20
-30
-40
Observed-Predicted Blood Lead, µg/dl
Observed-Predicted Using Estimated Dust Lead
Observed-Predicted Using Observed Dust Lead
0-249
250-499
500-749
750-999
1000-1499
1500-1999
2000-2999
3000-9999
10,000+
Observed Dust Lead Concentration, ppm

Figure 25

TECHNICAL APPENDIX A

Bivariate Correlations and Relationships Among the Data

Based on preliminary assessments, the list of variables used in U.S. EPA's analyses was reduced to a manageable set of 31 variables. They may be characterized as follows, using variable names in U.S. EPA's analyses and some recoding for clarity:

Response variable LOGPBB = natural logarithm of blood lead;

Location LOGDIST = natural logarithm of distance from NL/Taracorp lead smelter, in rings of about 1/8 mile, coded 1 to 10;

Environmental lead variables

LOGPBD = natural logarithm of dust lead concentration;

LOGPBDL = natural logarithm of dust lead loading;

LOGPBS = natural logarithm of soil lead concentration;

LOGPBW = natural logarithm of water lead concentration;

LOGXRFMN = natural logarithm of average lead paint loading measured by XRF, plus 1;

LOGCXI = natural logarithm of interior lead paint loading times paint condition, plus 1;

LOGCXO = natural logarithm of exterior lead paint loading times paint condition, plus 1;

REFINISH = refinishing or paint removal done within last year (0 = no, 1 = yes);

Demographic and household variables

AIRCOND = air conditioner used (0 = no, 1 = yes);

BLDCONIM = building condition, with imputation (1, 2, or 3 if not missing; 1.389 if missing);

CIGSDAY = number of cigarettes smoked per day;

EDUCYRS = educational attainment, in years;

INCOME = total household income, coded 0 to 9 in intervals of $5000;

LOGDSTLD = natural logarithm of total dust loading;

LOGYRS = natural logarithm of time at residence, in years;

NONWHITE = parents Afro-American, Asian, Pacific Islander or Native American (0 if no, 1 if yes);

NUMSMOKE = number of smokers in household;

RENT_OWN = rental housing (0 if no, 1 if yes);

USEDSLAG = slag used as fill on property (0 = no, 1 = yes);

Individual child variables

AGE = child's age in years;

AGE2SQR = (age - 2 years), squared;

FOLK_MED = folk medicine used (0 = no, 1 = yes);

HRS_HOME = hours spent at home, per week;

MOUTHFR = mouthing frequency, coded 0, 1, 3, or 10 for never, almost never, once in a while, a lot;

OUTPLHRS = hours spent playing outside, per day;

PAINTFR = frequency of eating paint, coded 0, 1, 3, or 10 for never, almost never, once in a while, a lot;

PLAYFLR = hours spent playing on floor;

SEX = child's sex (0= male, 1 = female);

SUCKTHUM = child sucks thumb (0 = no, 1 = yes);

The correlations involve both household and environmental factors on a household unit level, and individual child factors. U.S. EPA therefore calculated the correlation matrix from the complete child data set, which implicitly weights each household or environmental correlation by the number of children in that household. In U.S. EPA's opinion, from a risk assessment perspective, this is an appropriate weighting. Correlations calculated from the household-level data set show little difference, however. The results are shown in the Appendix. Tables A-1, A-2 and A-3. Table A-1 shows the Pearson bivariate correlation coefficients, in a triangular matrix format to avoid clutter. Since the correlation between variables X and Y is the same as the correlation between variables Y and X, any entry not found by looking for X in the row list and Y in the column list can be found at Y in the row list and X in the column list. A correlation coefficient of 1 means a perfect positive linear relationship exists, $Y = a + bX$, where b is a positive number. A correlation coefficient of -1 means that a perfect linear relationship exists, where b is a negative number. A correlation coefficient of 0 means that there is no linear relationship between the variables, on average. Table A-2 gives the number of pairs of measurements in which both variables are not missing, so that the correlation coefficient is calculated using only those pairs. Note that there are many missing values, but that the pattern shifts depending on which pairs of variables are being considered. The statistical significance (denoted P) of each correlation coefficient is given in Table A-3. Note that because of the large sample size, even relatively small correlation coefficients of about 0.1 are statistically significant by conventional criteria ($P < 0.05$).

TABLE A1. PEARSON CORRELATION MATRIX FOR 31 VARIABLES IN MADISON COUNTY LEAD STUDY

	Response	Location	Environmental		
	LOGPBB	LOGDIST	LOGPBD	LOGPBDL	LOGPBS
Response Variable					
LOGPBB	1.000				
Location Variable					
LOGDIST	-0.257	1.000			
Environmental Variables					
LOGPBD	0.307	-0.243	1.000		
LOGPBDL	0.425	-0.219	0.824	1.000	
LOGPBS	0.249	-0.522	0.440	0.433	1.000
LOGPBW	0.084	-0.005	0.023	0.011	0.086
LOGXRFMN	0.105	-0.066	0.393	0.381	0.295
LOGCXI	0.163	-0.011	0.432	0.405	0.337
LOGCXO	0.077	0.048	0.360	0.301	0.278
REFINISH	0.114	0.038	0.085	0.056	0.065
Household and Demographic Variables					
AIRCOND	-0.267	0.189	-0.196	-0.272	-0.149
BLDCONIM	0.311	-0.266	0.215	0.334	0.180
CIGSDAY	0.229	-0.269	0.108	0.150	0.168
EDUCYRS	-0.292	0.148	-0.078	-0.166	-0.114
INCOME	-0.258	0.170	-0.024	-0.160	-0.112
LOGDSTLD	0.332	-0.051	0.107	0.652	0.174
LOGYRS	-0.082	0.039	-0.013	-0.016	-0.102
NONWHITE	0.107	0.180	-0.204	-0.069	-0.183
NUMSMOKE	0.161	-0.226	0.095	0.141	0.158
RENT OWN	0.222	-0.117	0.114	0.180	0.198
USEDSLAG	-0.004	0.054	-0.038	-0.003	-0.093
Individual and Behavioral Variables					
AGE	-0.039	-0.040	0.053	0.069	0.062
AGE2SQR	-0.120	-0.037	0.046	0.049	0.064
FOLK MED	-0.018	-0.052	-0.019	-0.041	0.044
HRS HOME	0.109	-0.056	0.008	0.079	-0.010
MOUTHFR	0.030	-0.033	0.011	0.013	0.019
OUTPLHRS	0.229	-0.167	0.010	0.078	0.081
EATPNTFR	0.049	-0.049	0.058	0.025	0.016
PLAYFLR	0.052	-0.038	0.067	0.056	0.049
SEX	-0.097	0.095	-0.061	-0.076	-0.085
SUCKTHUM	0.069	-0.152	-0.027	0.011	0.069

TABLE A1 (cont'd). PEARSON CORRELATION MATRIX FOR 31 VARIABLES IN MADISON COUNTY LEAD STUDY

	Environmental Variables				
	LOGPBW	LOGXRFMN	LOGCXI	LOGCXO	REFINISH
Environmental Variables					
LOGPBW	1.000				
LOGXRFMN	0.022	1.000			
LOGCXI	0.038	0.917	1.000		
LOGCXO	-0.016	0.333	0.477	1.000	
REFINISH	0.084	0.072	0.173	0.013	1.000
Household and Demographic Variables					
AIRCOND	0.059	-0.032	-0.083	-0.069	0.104
BLDCONIM	0.041	0.058	0.119	0.172	-0.139
CIGSDAY	-0.173	0.009	0.002	0.111	0.030
EDUCYRS	0.105	0.005	0.016	0.019	0.029
INCOME	-0.018	0.007	0.025	0.086	0.059
LOGDSTLD	-0.007	0.146	0.133	0.042	-0.015
LOGYRS	0.014	0.018	0.055	0.027	-0.008
NONWHITE	-0.053	-0.059	-0.065	-0.215	-0.097
NUMSMOKE	-0.023	0.060	0.027	0.067	0.056
RENT OWN	0.028	-0.064	-0.001	0.041	-0.018
USEDSLAG	-0.010	0.050	0.016	0.039	0.000
Individual and Behavioral Variables					
AGE	0.060	0.039	0.047	0.076	0.044
AGE2SQR	0.033	0.050	0.030	0.054	0.045
FOLK MED	0.026	-0.020	-0.030	-0.063	0.033
HRS HOME	-0.128	0.057	0.019	-0.012	0.054
MOUTHFR	-0.041	0.000	0.037	0.034	0.089
OUTPLHRS	-0.016	0.016	0.045	-0.003	0.054
EATPNTFR	0.057	0.022	0.013	-0.043	0.054
PLAYFLR	-0.031	0.013	0.046	0.093	0.005
SEX	0.037	-0.052	-0.074	-0.058	-0.040
SUCKTHUM	0.009	0.022	-0.017	-0.032	-0.012

		Household and Demographic Variables			
	AIRCOND	BLDCONIM	CIGSDAY	EDUCYRS	INCOME
Household and Demographic Variables					
AIRCOND	1.000				
BLDCONIM	-0.243	1.000			
CIGSDAY	-0.241	0.235	1.000		
EDUCYRS	0.375	-0.335	-0.339	1.000	

TABLE A1 (cont'd). PEARSON CORRELATION MATRIX FOR 31 VARIABLES IN MADISON COUNTY LEAD STUDY

	AIRCOND	BLDCONIM	CIGSDAY	EDUCYRS	INCOME
Household and Demographic Variables					
INCOME	0.250	-0.272	-0.201	0.357	1.000
LOGDSTLD	-0.215	0.298	0.117	-0.185	-0.257
LOGYRS	0.123	-0.064	-0.045	0.144	0.247
NONWHITE	-0.116	-0.106	-0.190	-0.114	-0.283
NUMSMOKE	-0.048	0.265	0.547	-0.223	-0.165
RENT OWN	-0.150	0.253	0.124	-0.273	-0.519
USEDSLAG	-0.072	0.024	-0.049	-0.070	-0.140
Individual and Behavioral Variables					
AGE	0.020	-0.001	0.061	-0.006	0.014
AGE2SQR	0.031	-0.020	0.013	-0.004	0.025
FOLK MED	-0.053	-0.034	0.032	0.000	0.048
HRS HOME	-0.053	0.029	0.073	-0.086	-0.136
MOUTHFR	-0.026	0.039	-0.019	0.037	-0.054
OUTPLHRS	-0.113	0.134	0.277	-0.115	-0.033
EATPNTFR	-0.050	-0.001	0.004	-0.041	-0.085
PLAYFLR	0.051	0.059	0.062	-0.003	-0.006
SEX	0.073	-0.024	-0.081	0.058	-0.020
SUCKTHUM	-0.049	0.083	0.080	-0.095	-0.089

	LOGDSTLD	LOGYRS	NONWHITE	NUMSMOKE	RENT OWN
LOGDSTLD	1.000				
LOGYRS	-0.010	1.000			
NONWHITE	0.155	-0.101	1.000		
NUMSMOKE	0.117	-0.008	-0.122	1.000	
RENT OWN	0.167	-0.372	0.177	0.171	1.000
USEDSLAG	0.046	-0.103	0.004	0.014	0.192
AGE	0.053	0.370	-0.021	0.028	-0.049
AGE2SQR	0.026	0.245	-0.026	0.016	-0.064
FOLK MED	-0.048	0.033	-0.142	-0.106	-0.103
HRS HOME	0.124	-0.083	-0.010	0.019	0.035
MOUTHFR	0.008	-0.270	-0.105	0.003	0.010
OUTPLHRS	0.124	0.224	-0.062	0.212	-0.004
EATPNTFR	-0.033	-0.030	-0.004	-0.009	0.046
PLAYFLR	0.001	-0.112	-0.146	0.100	0.081
SEX	-0.046	-0.034	0.057	-0.031	0.118
SUCKTHUM	0.053	0.080	0.067	0.039	0.050

TABLE A1 (cont'd). PEARSON CORRELATION MATRIX FOR 31 VARIABLES IN MADISON COUNTY LEAD STUDY

	Individual and Behavioral Variables				
	USEDSLAG	AGE	AGE2SQR	FOLK MED	HRS HOME
USEDSLAG	1.000				
Individual and Behavioral Variables					
AGE	-0.017	1.000			
AGE2SQR	-0.029	0.875	1.000		
FOLK_MED	-0.032	-0.002	-0.000	1.000	
HRS_HOME	0.036	-0.184	-0.159	-0.016	1.000
MOUTHFR	0.031	-0.496	-0.346	-0.065	0.064
OUTPLHRS	-0.031	0.420	0.285	0.011	-0.010
EATPNTFR	-0.054	-0.048	-0.049	0.005	-0.008
PLAYFLR	-0.055	-0.275	-0.282	0.050	0.201
SEX	0.060	-0.045	-0.051	-0.039	0.006
SUCKTHUM	-0.033	0.219	0.149	0.056	-0.064

	Individual and Behavioral Variables				
	MOUTHFR	OUTPLHRS	EATPNTFR	PLAYFLR	SEX
Individual and Behavioral Variables					
MOUTHFR	1.000				
OUTPLHRS	-0.197	1.000			
EATPNTFR	0.111	-0.036	1.000		
PLAYFLR	0.148	-0.170	0.063	1.000	
SEX	0.042	-0.071	-0.056	-0.069	1.000
SUCKTHUM	-0.190	0.131	0.027	-0.032	-0.079

	SUCKTHUM
SUCKTHUM	1.000

TABLE A2. FREQUENCY TABLE OF THE NUMBER OF NON-MISSING PAIRED OBSERVATIONS IN THE CORRELATION MATRIX FOR THE MADISON COUNTY ENVIRONMENTAL LEAD STUDY.

	LOGPBB	LOGDIST	LOGPBD	LOGPBDL	LOGPBS
LOGPBB	490				
LOGDIST	479	479			
LOGPBD	470	460	470		
LOGPBDL	466	456	466	466	
LOGPBS	474	464	467	463	474
LOGPBW	470	460	463	459	467
LOGXRFMN	457	448	456	454	454
LOGCXI	471	461	470	466	468
LOGCXO	480	474	462	458	466
REFINISH	473	463	455	451	458
AIRCOND	489	479	470	466	474
BLDCONIM	490	479	470	466	474
CIGSDAY	482	472	464	462	468
EDUCYRS	487	477	468	464	472
INCOME	475	465	456	452	460
LOGDSTLD	466	456	466	466	463
LOGYRS	488	477	469	465	473
NONWHITE	485	474	465	461	469
NUMSMOKE	487	477	468	464	472
RENT OWN	472	463	453	449	457
USEDSLAG	467	458	449	445	453
AGE	490	479	470	466	474
AGE2SQR	490	479	470	466	474
FOLK MED	484	473	464	460	468
HRS HOME	490	479	470	466	474
MOUTHFR	487	476	467	463	471
OUTPLHRS	490	479	470	466	474
EATPNTFR	486	475	466	462	470
PLAYFLR	487	476	468	464	472
SEX	490	479	470	466	474
SUCKTHUM	490	479	470	466	474

	LOGPBW	LOGXRFMN	LOGCXI	LOGCXO	REFINISH
LOGPBW	470				
LOGXRFMN	450	457			
LOGCXI	464	457	471		
LOGCXO	462	449	463	480	
REFINISH	454	441	455	465	473
AIRCOND	470	457	471	480	473
BLDCONIM	470	457	471	480	473
CIGSDAY	464	453	465	473	467

TABLE A2 (cont'd). FREQUENCY TABLE OF THE NUMBER OF NON-MISSING PAIRED OBSERVATIONS IN THE CORRELATION MATRIX FOR THE MADISON COUNTY ENVIRONMENTAL LEAD STUDY.

	LOGPBW	LOGXRFMN	LOGCXI	LOGCXO	REFINISH
EDUCYRS	468	455	469	478	471
INCOME	456	443	457	466	459
LOGDSTLD	459	454	466	458	451
LOGYRS	469	456	470	478	471
NONWHITE	468	452	466	475	468
NUMSMOKE	468	455	469	478	471
RENT OWN	453	440	454	463	458
USEDSLAG	449	436	450	460	454
AGE	470	457	471	480	473
AGE2SQR	470	457	471	480	473
FOLK MED	464	451	465	474	467
HRS HOME	470	457	471	480	473
MOUTHFR	467	454	468	477	470
OUTPLHRS	470	457	471	480	473
EATPNTFR	467	453	467	476	469
PLAYFLR	468	455	469	478	470
SEX	470	457	471	480	473
SUCKTHUM	470	457	471	480	473

	AIRCOND	BLDCONIM	CIGSDAY	EDUCYRS	INCOME
AIRCOND	489				
BLDCONIM	489	490			
CIGSDAY	482	482	482		
EDUCYRS	487	487	480	487	
INCOME	475	475	468	473	475
LOGDSTLD	466	466	462	464	452
LOGYRS	487	488	480	485	473
NONWHITE	484	485	477	482	470
NUMSMOKE	487	487	480	485	475
RENT OWN	472	472	465	470	458
USEDSLAG	467	467	460	465	453
AGE	489	490	482	487	475
AGE2SQR	489	490	482	487	475
FOLK MED	483	484	476	481	470
HRS HOME	489	490	482	487	475
MOUTHFR	486	487	479	484	472
OUTPLHRS	489	490	482	487	475
EATPNTFR	485	486	478	483	471
PLAYFLR	486	487	479	484	473
SEX	489	490	482	487	475
SUCKTHUM	489	490	482	487	475

TABLE A2 (cont'd). FREQUENCY TABLE OF THE NUMBER OF NON-MISSING PAIRED OBSERVATIONS IN THE CORRELATION MATRIX FOR THE MADISON COUNTY ENVIRONMENTAL LEAD STUDY.

	LOGDSTLD	LOGYRS	NONWHITE	NUMSMOKE	RENT OWN
LOGDSTLD	466				
LOGYRS	465	488			
NONWHITE	461	483	485		
NUMSMOKE	464	485	482	487	
RENT OWN	449	470	467	470	472
USEDSLAG	445	465	462	465	452
AGE	466	488	485	487	472
AGE2SQR	466	488	485	487	472
FOLK MED	460	482	479	482	466
HRS HOME	466	488	485	487	472
MOUTHFR	463	485	482	484	469
OUTPLHRS	466	488	485	487	472
EATPNTFR	462	484	481	483	468
PLAYFLR	464	485	482	484	469
SEX	466	488	485	487	472
SUCKTHUM	466	488	485	487	472

	USEDSLAG	AGE	AGE2SQR	FOLK MED	HRS HOME
USEDSLAG	467				
AGE	467	490			
AGE2SQR	467	490	490		
FOLK MED	461	484	484	484	
HRS HOME	467	490	490	484	490
MOUTHFR	464	487	487	481	487
OUTPLHRS	467	490	490	484	490
EATPNTFR	463	486	486	480	486
PLAYFLR	465	487	487	481	487
SEX	467	490	490	484	490
SUCKTHUM	467	490	490	484	490

	MOUTHFR	OUTPLHRS	EATPNTFR	PLAYFLR	SEX
MOUTHFR	487				
OUTPLHRS	487	490			
EATPNTFR	484	486	486		
PLAYFLR	484	487	483	487	
SEX	487	490	486	487	490
SUCKTHUM	487	490	486	487	490

	SUCKTHUM
SUCKTHUM	490

TABLE A3. MATRIX OF SIGNIFICANCE LEVELS (PROBABILITIES) FOR VARIABLES IN THE MADISON COUNTY ENVIRONMENTAL LEAD STUDY

	LOGPBB	LOGDIST	LOGPBD	LOGPBDL	LOGPBS
Response Variable					
LOGPBB	0.000				
Location Variable					
LOGDIST	0.000	0.000			
Environmental Variables					
LOGPBD	0.000	0.000	0.000		
LOGPBDL	0.000	0.000	0.000	0.000	
LOGPBS	0.000	0.000	0.000	0.000	0.000
LOGPBW	0.069	0.915	0.615	0.807	0.064
LOGXRFMN	0.024	0.162	0.000	0.000	0.000
LOGCXI	0.000	0.816	0.000	0.000	0.000
LOGCXO	0.092	0.301	0.000	0.000	0.000
REFINISH	0.013	0.412	0.070	0.239	0.165
Household and Demographic Variables					
AIRCOND	0.000	0.000	0.000	0.000	0.001
BLDCONIM	0.000	0.000	0.000	0.000	0.000
CIGSDAY	0.000	0.000	0.020	0.001	0.000
EDUCYRS	0.000	0.001	0.093	0.000	0.013
INCOME	0.000	0.000	0.613	0.001	0.017
LOGDSTLD	0.000	0.276	0.021	0.000	0.000
LOGYRS	0.070	0.392	0.778	0.727	0.026
NONWHITE	0.019	0.000	0.000	0.142	0.000
NUMSMOKE	0.000	0.000	0.039	0.002	0.001
RENT OWN	0.000	0.012	0.015	0.000	0.000
USEDSLAG	0.932	0.244	0.421	0.952	0.047
Individual and Behavioral Variables					
AGE	0.384	0.378	0.252	0.135	0.176
AGE2SQR	0.008	0.423	0.325	0.291	0.165
FOLK MED	0.691	0.262	0.685	0.375	0.340
HRS HOME	0.016	0.223	0.863	0.087	0.834
MOUTHFR	0.512	0.472	0.807	0.781	0.674
OUTPLHRS	0.000	0.000	0.829	0.091	0.079
EATPNTFR	0.279	0.289	0.212	0.589	0.726
PLAYFLR	0.256	0.403	0.145	0.226	0.293
SEX	0.032	0.038	0.187	0.102	0.064
SUCKTHUM	0.127	0.001	0.565	0.815	0.134

TABLE A3 (cont'd). MATRIX OF SIGNIFICANCE LEVELS (PROBABILITIES) FOR VARIABLES IN THE MADISON COUNTY ENVIRONMENTAL LEAD STUDY

	LOGPBW	LOGXRFMN	LOGCXI	LOGCXO	REFINISH
Environmental Variables					
LOGPBW	0.000				
LOGXRFMN	0.642	0.000			
LOGCXI	0.411	0.000	0.000		
LOGCXO	0.732	0.000	0.000	0.000	
REFINISH	0.073	0.134	0.000	0.784	0.000
Household and Demographic Variables					
AIRCOND	0.205	0.495	0.073	0.130	0.024
BLDCONIM	0.372	0.218	0.010	0.000	0.003
CIGSDAY	0.000	0.851	0.962	0.015	0.522
EDUCYRS	0.023	0.921	0.734	0.684	0.535
INCOME	0.698	0.883	0.599	0.064	0.207
LOGDSTLD	0.884	0.002	0.004	0.365	0.757
LOGYRS	0.755	0.694	0.233	0.562	0.860
NONWHITE	0.255	0.209	0.160	0.000	0.037
NUMSMOKE	0.616	0.201	0.565	0.144	0.226
RENT OWN	0.551	0.177	0.978	0.374	0.700
USEDSLAG	0.839	0.302	0.743	0.400	1.000
Individual and Behavioral Variables					
AGE	0.191	0.411	0.305	0.098	0.337
AGE2SQR	0.476	0.286	0.511	0.236	0.332
FOLK MED	0.581	0.665	0.525	0.169	0.481
HRS HOME	0.006	0.227	0.679	0.789	0.243
MOUTHFR	0.378	1.000	0.423	0.456	0.054
OUTPLHRS	0.730	0.731	0.335	0.956	0.243
EATPNTFR	0.221	0.634	0.782	0.352	0.239
PLAYFLR	0.501	0.785	0.317	0.043	0.919
SEX	0.419	0.269	0.110	0.207	0.381
SUCKTHUM	0.851	0.632	0.709	0.484	0.801

	AIRCOND	BLDCONIM	CIGSDAY	EDUCYRS	INCOME
Household and Demographic Variables					
AIRCOND	0.000				
BLDCONIM	0.000	0.000			
CIGSDAY	0.000	0.000	0.000		
EDUCYRS	0.000	0.000	0.000	0.000	
INCOME	0.000	0.000	0.000	0.000	0.000
LOGDSTLD	0.000	0.000	0.012	0.000	0.000

TABLE A3 (cont'd). MATRIX OF SIGNIFICANCE LEVELS (PROBABILITIES) FOR VARIABLES IN THE MADISON COUNTY ENVIRONMENTAL LEAD STUDY

	AIRCOND	BLDCONIM	CIGSDAY	EDUCYRS	INCOME
LOGYRS	0.007	0.158	0.329	0.001	0.000
NONWHITE	0.011	0.020	0.000	0.012	0.000
NUMSMOKE	0.290	0.000	0.000	0.000	0.000
RENT OWN	0.001	0.000	0.008	0.000	0.000
USEDSLAG	0.122	0.610	0.293	0.130	0.003
Individual and Behavioral Variables					
AGE	0.654	0.983	0.183	0.892	0.753
AGE2SQR	0.494	0.655	0.773	0.934	0.582
FOLK MED	0.245	0.453	0.485	0.994	0.300
HRS HOME	0.240	0.518	0.111	0.057	0.003
MOUTHFR	0.566	0.394	0.682	0.417	0.243
OUTPLHRS	0.013	0.003	0.000	0.011	0.470
EATPNTFR	0.267	0.985	0.928	0.364	0.064
PLAYFLR	0.260	0.192	0.175	0.947	0.888
SEX	0.108	0.597	0.077	0.205	0.664
SUCKTHUM	0.282	0.066	0.079	0.037	0.054
	LOGDSTLD	LOGYRS	NONWHITE	NUMSMOKE	RENT OWN
Household and Demographic Variables					
LOGDSTLD	0.000				
LOGYRS	0.822	0.000			
NONWHITE	0.001	0.026	0.000		
NUMSMOKE	0.011	0.852	0.007	0.000	
RENT OWN	0.000	0.000	0.000	0.000	0.000
USEDSLAG	0.329	0.026	0.929	0.756	0.000
Individual and Behavioral Variables					
AGE	0.256	0.000	0.650	0.536	0.289
AGE2SQR	0.569	0.000	0.568	0.719	0.163
FOLK MED	0.308	0.465	0.002	0.020	0.026
HRS HOME	0.007	0.066	0.820	0.680	0.442
MOUTHFR	0.856	0.000	0.022	0.942	0.833
OUTPLHRS	0.007	0.000	0.170	0.000	0.937
EATPNTFR	0.479	0.508	0.926	0.839	0.324
PLAYFLR	0.979	0.014	0.001	0.027	0.081
SEX	0.323	0.453	0.213	0.489	0.010
SUCKTHUM	0.249	0.078	0.139	0.393	0.276

TABLE A3 (cont'd). MATRIX OF SIGNIFICANCE LEVELS (PROBABILITIES) FOR VARIABLES IN THE MADISON COUNTY ENVIRONMENTAL LEAD STUDY

	USEDSLAG	AGE	AGE2SQR	FOLK MED	HRS HOME
USEDSLAG	0.000				
AGE	0.711	0.000			
AGE2SQR	0.526	0.000	0.000		
FOLK MED	0.487	0.972	0.996	0.000	
HRS HOME	0.435	0.000	0.000	0.718	0.000
MOUTHFR	0.509	0.000	0.000	0.156	0.159
OUTPLHRS	0.499	0.000	0.000	0.818	0.830
EATPNTFR	0.246	0.290	0.282	0.905	0.869
PLAYFLR	0.240	0.000	0.000	0.272	0.000
SEX	0.197	0.322	0.263	0.387	0.898
SUCKTHUM	0.472	0.000	0.001	0.222	0.158

	MOUTHFR	OUTPLHRS	EATPNTFR	PLAYFLR	SEX
MOUTHFR	0.000				
OUTPLHRS	0.000	0.000			
EATPNTFR	0.014	0.428	0.000		
PLAYFLR	0.001	0.000	0.164	0.000	
SEX	0.351	0.115	0.217	0.127	0.000
SUCKTHUM	0.000	0.004	0.556	0.476	0.082

	SUCKTHUM
SUCKTHUM	0.000

TECHNICAL APPENDIX B

Confounding: Identification, Analysis, Remedies

1. Identification of Confounding

According to Stellman (1987), confounding is the "cause of great angst among epidemiologists". This term refers to the incorrect assignment of a response (such as elevated blood lead concentration) to a given agent when in fact a third variable (the confounder) is responsible. A confounder must therefore be correlated with the effect or response variable, and must also be so strongly correlated with the nominal causal agent as to mask its effect on the response. It is also important that the confounder is not an intermediate step in the causal path between exposure and response or outcome (Rothman 1986). This last requirement turns out to be the critical issue in modelling lead exposure for Madison County children. However (Stellman 1987, p. 165), writes that "Rarely, however, does confounding itself, especially from unidentified sources, live up to its reputation by introducing seriously spurious associations." U.S. EPA's first goal is to identify whether confounding is a possibility in these data.

A more serious concern is "overcontrol", which occurs when a large number of non-pollution variables are used in a statistical model in order to explain the observed response with anything except the nominal causal agent. This can be done unconsciously, when an investigator who has little understanding of the substantive issues in environmental exposure to a pollutant throws in every variable that has been measured, including all possible demographic and behavioral variables and their combinations and interactions, hoping that the truth will come out at the end of a complicated multivariate analysis. Whether done deliberately or not, the consequence of an unguided search for predictive relationships is to obscure true relationships with environmental pollutants. Unfortunately, the uninformed use of sophisticated computer programs, such as those for stepwise regression modelling, makes it easy to carry out an unguided search. U.S. EPA's second goal in this section is to devise strategies for modelling the relationship of environmental lead to blood lead.

Identification of potential confounding in linear regression models (which will be used exclusively here, as in the IDPH report, but with two alternative specifications) is easily done using the correlation matrix calculated in Section 2.8. First of all, a confounder must be more or less strongly correlated with both the response (LOGPBB = logarithm of blood lead) and the nominal causal agent (LOGPBS = logarithm of soil lead). "Strongly correlated" is not well defined. In view of the large sample size (490 children), almost all Pearson correlation coefficients in Table 6 are statistically significant. In a very thoughtful discussion of modelling the relationship between child development and blood lead, Dietrich et al. (1986) suggest defining a potential confounder as one with $P \leq 0.10$ for both response and agent (LOGPBB and LOGPBS in this case), but a more stringent requirement should be used here because of the large sample size, which magnifies the importance of even small effects. U.S. EPA will call a variable a strong confounder if $P < 0.001$ for correlation with both LOGPBB and LOGPBS, a strong covariate if $P < 0.001$ for correlation with LOGPBB and $P > 0.05$ for correlation with LOGPBS. In order to explore a wider range of alternatives, however, U.S. EPA will also call a variable a weak confounder if $0.001 < P < 0.05$ for correlation with LOGPBB and $P < 0.001$ for correlation with LOGPBS, or if $P < 0.001$ for correlation with LOGPBB and $0.001 < P < 0.05$ for correlation with LOGPBS.

The strong confounders, strong covariates, and weak confounders are shown in Table B-1, along with their bivariate Pearson correlation coefficients and P-values. Not surprisingly, household dust loading and dust lead are among the most important "strong confounders". Exterior condition of the building, and presence of air conditioning are also "strong confounders". Education and income are well correlated with blood lead, but are only "weak confounders" since they have only a modest correlation with soil lead. Distance from the NL/Taracorp lead smelter is a "strong confounder", but is much less strong than the variables mentioned previously. Soil lead is also a "strong confounder" with itself, but is much less strong than the other variables mentioned previously. Table B-1a lists the strong confounders, Table B-1b lists the weak confounders, Table B-1c lists the covariates, and Table B-1d lists the predictors of soil lead that are not predictive of blood lead.

Various schemes have been devised to prevent "overcontrol", based on first testing the confounders, then the strong covariates of LOGPBB, and finally some interaction terms (Dietrich et al. 1986; Kleinbaum and Muller 1986). As was shown in Section 4, variations in model selection strategies have almost no effect on the set of predictor variables selected by the model, except for the perfectly collinear set of dust lead variables. A key element in the preferred set of model selection strategies is that variables -- especially confounded variables -- be entered in about the same order as their bivariate correlations with the response variable, LOGPBB. This allows the appropriate index or best surrogate for LOGPBS to be used. In this case, the best surrogate is some set of household dust lead or dust loading variables, then building condition and distance from the NL/Taracorp lead lead smelter as less adequate characterizations of soil lead exposure. These are not truly surrogate variables, but are better described as preceding steps on a causal pathway.

2 Multivariate Characterization of Confounding

While confounding is a conceptual problem in epidemiology, identification of potential confounding is often a merely technical problem when any regression-like procedure is used to model the relationship between the response and the nominal causal agent(s). In a technical sense, confounding is only possible among measured variables of a data set when one of the predictor variables, the nominal causal agent such as LOGPBS, is very nearly a linear combination of other predictor variables in the data set. Confounding with variables that are not measured is a conceptual problem, of course, but is not capable of assessment by the data alone. Thus, soil lead (LOGPBS) is profoundly confounded with other variables, such as dust lead concentration (LOGPBD) or dust lead loading (LOGPBDL) only if there is some linear combination of dust lead variables and, possibly, distance or sociodemographic variables that together provide an almost perfect linear prediction of LOGPBS.

The easiest way to identify the existence of such a linear combination is to carry out a principal components analysis (PCA) of the correlation matrix, or equivalent covariance matrix or sum of squares and crossproducts matrix of the predictor variables. PCA involves only a linear transformation of the predictor variable data, without possible distortions that may be introduced in certain forms of rotated factor analysis. The output of a PCA produces two kinds of output: (1) latent roots or eigenvalues of the predictor variable correlation matrix (or its equivalent); (2) principal component loadings on standardized predictor variables corresponding to each eigenvalue. The eigenvalues of a correlation matrix or covariance matrix are always non-negative. For a correlation matrix with k predictors, the sum of the eigenvalues is always equal to k, so that the average eigenvalue is equal to 1.

Suppose that the eigenvalues are ordered from largest to smallest. The condition number for the ith principal component is calculated as the ratio of the largest eigenvalue to the ith eigenvalue. A useful rule of thumb is that if the condition number of the ith principal component is greater than about 30, there is a serious collinearity in the predictor variable data set (Belsley et al. 1981). Other criteria have been proposed for collinearity, such as having an eigenvalue for a PC that is smaller than 0.05. Collinearity could result a serious increase in the estimated standard error of a regression coefficient, thus reducing the inferred statistical significance of the most important predictor variables in that data set. There is also a much larger chance that the sign of the estimated regression coefficient will be the opposite of its true sign -- that is, showing that lead pollution is good for children. It is thus useful to examine the largest predictor variable loadings in PC's with small eigenvalues or large condition numbers, so as to identify the variables for which confounding is a potentially serious problem.

The eigenvalues for the 30 predictor variables in Table A-1 to Table A-3 are shown in Table B-2. Eigenvalue 30 is only 0.000001, so that there is evidence of an almost perfect collinearity. Examination of the principal component leading for PC 30 in Table B-3 shows that there only three variables involved in PC30: LOGPBDL, LOGPBD, and LOGDSTLD, which U.S. EPA has already shown to be perfectly collinear to within numerical roundoff error.

The maximum eigenvalue is 4.002, and the eigenvalues for PC's 26, 27, 28, and 29 respectively are 0.308, 0.282, 0.087, and 0.067 respectively from Table 10. The respective condition numbers are 12.99, 14.19, 46.00, and 59.73. PC 29 involves only two variables to any extent, LOGCXI and LOGXRFMN. These variables are not perfectly collinear, but clearly should not be used together in a model. Likewise, PC 28 involves mainly AGE and AGE2SQR, which are known to be rather well correlated. PC 27 does not have a critically high condition number, 14.19, but its major components are LOGPBS, LOGDIST, CIGSDAY, and LOGCXO. The numerical loadings suggest that there is roughly an inverse relationship between soil lead and distance after adjusting for the effects of deteriorating exterior lead-based paint and some socio-demographic factors. PC 26 involves a more complicated combination of LOGPBS, LOGDIST, CIGSDAY, INCOME, RENT_OWN, and NUMSMOKE. Nothing in these PC's suggest that there is such profound confounding between soil lead and dust lead as to prevent estimation of separate contributions to blood lead.

It is useful to recall here that Rothman (1986) excludes from confounding those variables that characterize a causal pathway relationship between the nominal causal agent and the response. Precisely this situation exists for soil lead, dust lead, and child blood lead, with the confounder (dust lead) occupying an intermediate place between soil lead and blood lead. This is discussed further in Section 6.

TABLE B-1. CONFOUNDERS AND COVARIATES OF THE RELATIONSHIP BETWEEN LOG BLOOD LEAD AND LOG SOIL LEAD

TABLE B-1A. STRONG CONFOUNDERS

VARIABLE	CORREL. LOGPBB	P	RANK OF CORREL.	CORREL. LOGPBS	P	RANK OF CORREL.
LOGPBDL	0.425	0.000	1	0.433	0.000	3
LOGDSTLD	0.332	0.000	2	0.174	0.000	10
BLDCONIM	0.311	0.000	3	0.180	0.000	9
LOGPBD	0.307	0.000	4	0.440	0.000	2
AIRCOND	-0.267	0.000	6	-0.149	0.001	13
LOGDIST	-0.257	0.000	8	-0.522	0.000	1
LOGPBS	0.249	0.000	9	1.000	---	---
CIGSDAY	0.229	0.000	10	0.168	0.000	11
RENT OWN	0.222	0.000	12	0.198	0.000	7
LOGCXI	0.163	0.000	13	0.337	0.000	4
NUMSMOKE	0.161	0.000	14	0.158	0.001	12

TABLE B-1B. WEAK CONFOUNDERS

VARIABLE	CORREL. LOGPBB	P	RANK OF CORREL.	CORREL. LOGPBS	P	RANK OF CORREL.
EDUCYRS	-0.292	0.000	5	-0.114	0.013	14
INCOME	-0.258	0.000	7	-0.112	0.017	15
NONWHITE	0.107	0.019	18	-0.183	0.000	8
LOGXRFMN	0.105	0.024	19	0.295	0.000	5

TABLE B1-C. COVARIATES OF LOG BLOOD LEAD

VARIABLE	CORREL. LOGPBB	P	RANK OF CORREL.	CORREL. LOGPBS	P	RANK OF CORREL.
OUTPLHRS	0.229	0.000	11	0.081	0.079	19
AGE2SQR	-0.120	0.008	15	0.064	0.165	21
REFINISH	0.114	0.013	16	0.065	0.165	20
HRS HOME	0.109	0.016	17	-0.010	0.834	22
SEX	-0.097	0.032	20	-0.085	0.064	18

TABLE B1-D. COVARIATES OF LOG SOIL LEAD

VARIABLE	CORREL. LOGPBB	P	RANK OF CORREL.	CORREL. LOGPBS	P	RANK OF CORREL.
LOGCXO	0.077	0.092	22	0.278	0.000	6
LOGYRS	-0.082	0.070	21	-0.102	0.026	16
USEDSLAG	-0.004	0.932	23	0.093	0.047	17

TABLE B-2. LATENT ROOTS (EIGENVALUES) OF PREDICTOR VARIABLE PRINCIPAL COMPONENTS

RANK	1	2	3	4	5
	4.002	3.025	2.656	1.779	1.435
RANK	6	7	8	9	10
	1.404	1.317	1.155	1.131	1.041
RANK	11	12	13	14	15
	1.004	0.931	0.913	0.881	0.829
RANK	16	17	18	19	20
	0.799	0.732	0.680	0.633	0.588
RANK	21	22	23	24	25
	0.567	0.524	0.465	0.414	0.350
RANK	26	27	28	29	30
	0.308	0.282	0.087	0.067	0.0000001

ATTACHMENT 4

STATISTICAL ANALYSES OF DATA FROM THE MADISON COUNTY LEAD STUDY AND IMPLICATIONS FOR REMEDIATION OF LEAD-CONTAMINATED SOIL

Allan H. Marcus, PhD
Environmental Criteria and Assessment Office
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

TECHNICAL APPENDIX C

IEUBK PARAMETER SAVE FILES FOR MODEL SENSITIVITY RUNS

GCFI2900.sv3
soil-to-dust coefficient = 0.29
Lead paint chip absorption = 0 percent

0.100 2.0 32.0 1.0
0.100 3.0 32.0 2.0
0.100 5.0 32.0 3.0
0.100 5.0 32.0 4.0
0.100 5.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 0 0 30.0
5.53 50.0
5.78 50.0
6.49 50.0
6.24 50.0
6.01 50.0
6.34 50.0
7.00 50.0
0 0.000 0.000 0.000 0.000
0.0 0.0 0.0 0.0
0.20 50.0
0.50 50.0
0.52 50.0
0.53 50.0
0.55 50.0
0.58 50.0
0.59 50.0
0 4.00 1.00 4.00 10.00
50.0 15.0
0.0 0.0 0.085 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.100 30.0 30.0
0.0 0.0 0.090 30.0 30.0
0.0 0.0 0.085 30.0 30.0
0 0 0
45.0 0.29 100.0 200.0 200.0
1200.0 200.0 200.0 200.0 1200.0
0.0 0.0 0.0 0.0 0.0
0.00 30.0
0.00 30.0

0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
1.600000 10.000000
0.100 0.333
20.000 0.333
10.000 0.333
10.000 0.333
10.000 0.333
1.000 0.333
100.000 0.333
0.750 0.333
0.750 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
1.00 1.00 1.00 1.00 1.00
0.30 0.30 0.50 0.00 0.50
0.20 0.20 0.20 0.20 0.20
1.0 1.0 1.0 1.0 1.0
9.0 1.0 6.0 0.060 0.200 0.060
1.0 1.0 1.0 1.0
9.00 9.00 2.0 0.0
10.0 10.0 10.0 50.0
0.020 200.0 1000.0 0.10
0.00 0.00 30.0 0

GCFI3800.sv3
soil-to-dust coefficient = 0.385
Lead paint chip absorption = 0 percent

0.100 2.0 32.0 1.0
0.100 3.0 32.0 2.0
0.100 5.0 32.0 3.0
0.100 5.0 32.0 4.0
0.100 5.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 7.0 32.0 4.0

0.100 0 0 30.0
5.53 50.0
5.78 50.0
6.49 50.0
6.24 50.0
6.01 50.0
6.34 50.0
7.00 50.0
0 0.000 0.000 0.000 0.000
0.0 0.0 0.0 0.0
0.20 50.0
0.50 50.0
0.52 50.0
0.53 50.0
0.55 50.0
0.58 50.0
0.59 50.0
0 4.00 1.00 4.00 10.00
50.0 15.0
0.0 0.0 0.085 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.100 30.0 30.0
0.0 0.0 0.090 30.0 30.0
0.0 0.0 0.085 30.0 30.0
0 0 0
45.0 0.38 100.0 200.0 200.0
1200.0 200.0 200.0 200.0 1200.0
0.0 0.0 0.0 0.0 0.0
0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
1.600000 10.000000
0.100 0.333
20.000 0.333
10.000 0.333
10.000 0.333
10.000 0.333
1.000 0.333

100.000 0.333
0.750 0.333
0.750 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
1.00 1.00 1.00 1.00 1.00
0.30 0.30 0.50 0.00 0.50
0.20 0.20 0.20 0.20 0.20
1.0 1.0 1.0 1.0 1.0
9.0 1.0 6.0 0.060 0.200 0.060
1.0 1.0 1.0 1.0
9.00 9.00 2.0 0.0
10.0 10.0 10.0 50.0
0.020 200.0 1000.0 0.10
0.00 0.00 30.0 0

GCFI5500.sv3
soil-to-dust coefficient = 0.55
Lead paint chip absorption = 0 percent

0.100 2.0 32.0 1.0
0.100 3.0 32.0 2.0
0.100 5.0 32.0 3.0
0.100 5.0 32.0 4.0
0.100 5.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 0 0 30.0
5.53 50.0
5.78 50.0
6.49 50.0
6.24 50.0
6.01 50.0
6.34 50.0
7.00 50.0
0 0.000 0.000 0.000 0.000
0.0 0.0 0.0 0.0

0.20 50.0
0.50 50.0
0.52 50.0
0.53 50.0
0.55 50.0
0.58 50.0
0.59 50.0
0 4.00 1.00 4.00 10.00
50.0 15.0
0.0 0.0 0.085 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.100 30.0 30.0
0.0 0.0 0.090 30.0 30.0
0.0 0.0 0.085 30.0 30.0
0 0 0
45.0 0.55 100.0 200.0 200.0
1200.0 200.0 200.0 200.0 1200.0
0.0 0.0 0.0 0.0 0.0
0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
1.600000 10.000000
0.100 0.333
20.000 0.333
10.000 0.333
10.000 0.333
10.000 0.333
1.000 0.333
100.000 0.333
0.750 0.333
0.750 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
1.00 1.00 1.00 1.00 1.00

0.30 0.30 0.50 0.00 0.50
0.20 0.20 0.20 0.20 0.20
1.0 1.0 1.0 1.0 1.0
9.0 1.0 6.0 0.060 0.200 0.060
1.0 1.0 1.0 1.0
9.00 9.00 2.0 0.0
10.0 10.0 10.0 50.0
0.020 200.0 1000.0 0.10
0.00 0.00 30.0 0

GCFI7000.sv3
soil-to-dust coefficient = 0.70
Lead paint chip absorption = 0 percent

0.100 2.0 32.0 1.0
0.100 3.0 32.0 2.0
0.100 5.0 32.0 3.0
0.100 5.0 32.0 4.0
0.100 5.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 0 0 30.0
5.53 50.0
5.78 50.0
6.49 50.0
6.24 50.0
6.01 50.0
6.34 50.0
7.00 50.0
0 0.000 0.000 0.000 0.000
0.0 0.0 0.0 0.0
0.20 50.0
0.50 50.0
0.52 50.0
0.53 50.0
0.55 50.0
0.58 50.0
0.59 50.0
0 4.00 1.00 4.00 10.00
50.0 15.0
0.0 0.0 0.085 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0

0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.100 30.0 30.0
0.0 0.0 0.090 30.0 30.0
0.0 0.0 0.085 30.0 30.0
0 0 0
45.0 0.70 100.0 200.0 200.0
1200.0 200.0 200.0 200.0 1200.0
0.0 0.0 0.0 0.0 0.0
0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
0.00 30.0
1.600000 10.000000
0.100 0.333
20.000 0.333
10.000 0.333
10.000 0.333
10.000 0.333
1.000 0.333
100.000 0.333
0.750 0.333
0.750 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
1.00 1.00 1.00 1.00 1.00
0.30 0.30 0.50 0.00 0.50
0.20 0.20 0.20 0.20 0.20
1.0 1.0 1.0 1.0 1.0
9.0 1.0 6.0 0.060 0.200 0.060
1.0 1.0 1.0 1.0
9.00 9.00 2.0 0.0
10.0 10.0 10.0 50.0
0.020 200.0 1000.0 0.10
0.00 0.00 30.0 0

GCFI2901.sv3

soil-to-dust coefficient = 0.29
Lead paint chip absorption = 1 percent

0.100 2.0 32.0 1.0
0.100 3.0 32.0 2.0
0.100 5.0 32.0 3.0
0.100 5.0 32.0 4.0
0.100 5.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 0 0 30.0
5.53 50.0
5.78 50.0
6.49 50.0
6.24 50.0
6.01 50.0
6.34 50.0
7.00 50.0
0 0.000 0.000 0.000 0.000
0.0 0.0 0.0 0.0
0.20 50.0
0.50 50.0
0.52 50.0
0.53 50.0
0.55 50.0
0.58 50.0
0.59 50.0
0 4.00 1.00 4.00 10.00
50.0 15.0
0.0 0.0 0.085 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.100 30.0 30.0
0.0 0.0 0.090 30.0 30.0
0.0 0.0 0.085 30.0 30.0
0 0 0
45.C 0.29 100.0 200.0 200.0
1200.0 200.0 200.0 200.0 1200.0
0.0 0.0 0.0 0.0 0.0
240.00 30.0
400.00 30.0
400.00 30.0
400.00 30.0

300.00 30.0
270.00 30.0
240.00 30.0
1.600000 10.000000
0.100 0.333
20.000 0.333
10.000 0.333
10.000 0.333
10.000 0.333
1.000 0.333
100.000 0.333
0.750 0.333
0.750 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
1.00 1.00 1.00 1.00 1.00
0.30 0.30 0.50 0.01 0.50
0.20 0.20 0.20 0.20 0.20
1.0 1.0 1.0 1.0 1.0
9.0 1.0 6.0 0.060 0.200 0.060
1.0 1.0 1.0 1.0
9.00 9.00 2.0 0.0
10.0 10.0 10.0 50.0
0.020 200.0 1000.0 0.10
0.00 0.00 30.0 0

GCFI3801.sv3
soil-to-dust coefficient = 0.385
Lead paint chip absorption = 1 percent

0.100 2.0 32.0 1.0
0.100 3.0 32.0 2.0
0.100 5.0 32.0 3.0
0.100 5.0 32.0 4.0
0.100 5.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 0 0 30.0

5.53 50.0
5.78 50.0
6.49 50.0
6.24 50.0
6.01 50.0
6.34 50.0
7.00 50.0
0 0.000 0.000 0.000 0.000
0.0 0.0 0.0 0.0
0.20 50.0
0.50 50.0
0.52 50.0
0.53 50.0
0.55 50.0
0.58 50.0
0.59 50.0
0 4.00 1.00 4.00 10.00
50.0 15.0
0.0 0.0 0.085 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.100 30.0 30.0
0.0 0.0 0.090 30.0 30.0
0.0 0.0 0.085 30.0 30.0
0 0 0
45.0 0.38 100.0 200.0 200.0
1200.0 200.0 200.0 200.0 1200.0
0.0 0.0 0.0 0.0 0.0
240.00 30.0
400.00 30.0
400.00 30.0
400.00 30.0
300.00 30.0
270.00 30.0
240.00 30.0
1.600000 10.000000
0.100 0.333
20.000 0.333
10.000 0.333
10.000 0.333
10.000 0.333
1.000 0.333
100.000 0.333

0.750 0.333
0.750 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
1.00 1.00 1.00 1.00 1.00
0.30 0.30 0.50 0.01 0.50
0.20 0.20 0.20 0.20 0.20
1.0 1.0 1.0 1.0 1.0
9.0 1.0 6.0 0.060 0.200 0.060
1.0 1.0 1.0 1.0
9.00 9.00 2.0 0.0
10.0 10.0 10.0 50.0
0.020 200.0 1000.0 0.10
0.00 0.00 30.0 0

GCFI5501.sv3
soil-to-dust coefficient = 0.55
Lead paint chip absorption = 1 percent

0.100 2.0 32.0 1.0
0.100 3.0 32.0 2.0
0.100 5.0 32.0 3.0
0.100 5.0 32.0 4.0
0.100 5.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 0 0 30.0
5.53 50.0
5.78 50.0
6.49 50.0
6.24 50.0
6.01 50.0
6.34 50.0
7.00 50.0
0 0.000 0.000 0.000 0.000
0.0 0.0 0.0 0.0
0.20 50.0
0.50 50.0

0.52 50.0
0.53 50.0
0.55 50.0
0.58 50.0
0.59 50.0
0 4.00 1.00 4.00 10.00
50.0 15.0
0.0 0.0 0.085 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.100 30.0 30.0
0.0 0.0 0.090 30.0 30.0
0.0 0.0 0.085 30.0 30.0
0 0 0
45.0 0.55 100.0 200.0 200.0
1200.0 200.0 200.0 200.0 1200.0
0.0 0.0 0.0 0.0 0.0
240.00 30.0
400.00 30.0
400.00 30.0
400.00 30.0
300.00 30.0
270.00 30.0
240.00 30.0
1.600000 10.000000
0.100 0.333
20.000 0.333
10.000 0.333
10.000 0.333
10.000 0.333
1.000 0.333
100.000 0.333
0.750 0.333
0.750 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
1.00 1.00 1.00 1.00 1.00
0.30 0.30 0.50 0.01 0.50
0.20 0.20 0.20 0.20 0.20

1.0 1.0 1.0 1.0 1.0
9.0 1.0 6.0 0.060 0.200 0.060
1.0 1.0 1.0 1.0
9.00 9.00 2.0 0.0
10.0 10.0 10.0 50.0
0.020 200.0 1000.0 0.10
0.00 0.00 30.0 0

GCFI7001.sv3
soil-to-dust coefficient = 0.70
Lead paint chip absorption = 1 percent

0.100 2.0 32.0 1.0
0.100 3.0 32.0 2.0
0.100 5.0 32.0 3.0
0.100 5.0 32.0 4.0
0.100 5.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 0 0 30.0
5.53 50.0
5.78 50.0
6.49 50.0
6.24 50.0
6.01 50.0
6.34 50.0
7.00 50.0
0 0.000 0.000 0.000 0.000
0.0 0.0 0.0 0.0
0.20 50.0
0.50 50.0
0.52 50.0
0.53 50.0
0.55 50.0
0.58 50.0
0.59 50.0
0 4.00 1.00 4.00 10.00
50.0 15.0
0.0 0.0 0.085 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.100 30.0 30.0

0.0 0.0 0.090 30.0 30.0
0.0 0.0 0.085 30.0 30.0
0 0 0
45.0 0.70 100.0 200.0 200.0
1200.0 200.0 200.0 200.0 1200.0
0.0 0.0 0.0 0.0 0.0
240.00 30.0
400.00 30.0
400.00 30.0
400.00 30.0
300.00 30.0
270.00 30.0
240.00 30.0
1.600000 10.000000
0.100 0.333
20.000 0.333
10.000 0.333
10.000 0.333
10.000 0.333
1.000 0.333
100.000 0.333
0.750 0.333
0.750 0.333
0.000 0.333

GCFI2902.sv3
soil-to-dust coefficient = 0.29
Lead paint chip absorption = 2 percent

0.100 2.0 32.0 1.0
0.100 3.0 32.0 2.0
0.100 5.0 32.0 3.0
0.100 5.0 32.0 4.0
0.100 5.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 0 0 30.0
5.53 50.0
5.78 50.0
6.49 50.0
6.24 50.0
6.01 50.0
6.34 50.0

7.00 50.0
0 0.000 0.000 0.000 0.000
0.0 0.0 0.0 0.0
0.20 50.0
0.50 50.0
0.52 50.0
0.53 50.0
0.55 50.0
0.58 50.0
0.59 50.0
0 4.00 1.00 4.00 10.00
50.0 15.0
0.0 0.0 0.085 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.100 30.0 30.0
0.0 0.0 0.090 30.0 30.0
0.0 0.0 0.085 30.0 30.0
0 0 0
45.0 0.29 100.0 200.0 200.0
1200.0 200.0 200.0 200.0 1200.0
0.0 0.0 0.0 0.0 0.0
240.00 30.0
400.00 30.0
400.00 30.0
400.00 30.0
300.00 30.0
270.00 30.0
240.00 30.0
1.600000 10.000000
0.100 0.333
20.000 0.333
10.000 0.333
10.000 0.333
10.000 0.333
1.000 0.333
100.000 0.333
0.750 0.333
0.750 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333

0.000 0.333
0.000 0.333
1.00 1.00 1.00 1.00 1.00
0.30 0.30 0.50 0.02 0.50
0.20 0.20 0.20 0.20 0.20
1.0 1.0 1.0 1.0 1.0
9.0 1.0 6.0 0.060 0.200 0.060
1.0 1.0 1.0 1.0
9.00 9.00 2.0 0.0
10.0 10.0 10.0 50.0
0.020 200.0 1000.0 0.10
0.00 0.00 30.0 0

GCFI3802.sv3
soil-to-dust coefficient = 0.385
Lead paint chip absorption = 2 percent

0.100 2.0 32.0 1.0
0.100 3.0 32.0 2.0
0.100 5.0 32.0 3.0
0.100 5.0 32.0 4.0
0.100 5.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 0 0 30.0
5.53 50.0
5.78 50.0
6.49 50.0
6.24 50.0
6.01 50.0
6.34 50.0
7.00 50.0
0 0.000 0.000 0.000 0.000
0.0 0.0 0.0 0.0
0.20 50.0
0.50 50.0
0.52 50.0
0.53 50.0
0.55 50.0
0.58 50.0
0.59 50.0
0 4.00 1.00 4.00 10.00
50.0 15.0
0.0 0.0 0.085 30.0 30.0

0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.100 30.0 30.0
0.0 0.0 0.090 30.0 30.0
0.0 0.0 0.085 30.0 30.0
0 0 0
45.0 0.38 100.0 200.0 200.0
1200.0 200.0 200.0 200.0 1200.0
0.0 0.0 0.0 0.0 0.0
240.00 30.0
400.00 30.0
400.00 30.0
400.00 30.0
300.00 30.0
270.00 30.0
240.00 30.0
1.600000 10.000000
0.100 0.333
20.000 0.333
10.000 0.333
10.000 0.333
10.000 0.333
1.000 0.333
100.000 0.333
0.750 0.333
0.750 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
1.00 1.00 1.00 1.00 1.00
0.30 0.30 0.50 0.02 0.50
0.20 0.20 0.20 0.20 0.20
1.0 1.0 1.0 1.0 1.0
9.0 1.0 6.0 0.060 0.200 0.060
1.0 1.0 1.0 1.0
9.00 9.00 2.0 0.0
10.0 10.0 10.0 50.0
0.020 200.0 1000.0 0.10
0.00 0.00 30.0 0

GCFI5502.sv3
soil-to-dust coefficient = 0.55
Lead paint chip absorption = 2 percent

0.100 2.0 32.0 1.0
0.100 3.0 32.0 2.0
0.100 5.0 32.0 3.0
0.100 5.0 32.0 4.0
0.100 5.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 0 0 30.0
5.53 50.0
5.78 50.0
6.49 50.0
6.24 50.0
6.01 50.0
6.34 50.0
7.00 50.0
0 0.000 0.000 0.000 0.000
0.0 0.0 0.0 0.0
0.20 50.0
0.50 50.0
0.52 50.0
0.53 50.0
0.55 50.0
0.58 50.0
0.59 50.0
0 4.00 1.00 4.00 10.00
50.0 15.0
0.0 0.0 0.085 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.100 30.0 30.0
0.0 0.0 0.090 30.0 30.0
0.0 0.0 0.085 30.0 30.0
0 0 0
45.0 0.55 100.0 200.0 200.0
1200.0 200.0 200.0 200.0 1200.0
0.0 0.0 0.0 0.0 0.0
240.00 30.0
400.00 30.0
400.00 30.0

400.00 30.0
300.00 30.0
270.00 30.0
240.00 30.0
1.600000 10.000000
0.100 0.333
20.000 0.333
10.000 0.333
10.000 0.333
10.000 0.333
1.000 0.333
100.000 0.333
0.750 0.333
0.750 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
1.00 1.00 1.00 1.00 1.00
0.30 0.30 0.50 0.02 0.50
0.20 0.20 0.20 0.20 0.20
1.0 1.0 1.0 1.0 1.0
9.0 1.0 6.0 0.060 0.200 0.060
1.0 1.0 1.0 1.0
9.00 9.00 2.0 0.0
10.0 10.0 10.0 50.0
0.020 200.0 1000.0 0.10
0.00 0.00 30.0 0

GCFI7002.sv3
soil-to-dust coefficient = 0.70
Lead paint chip absorption = 2 percent

0.100 2.0 32.0 1.0
0.100 3.0 32.0 2.0
0.100 5.0 32.0 3.0
0.100 5.0 32.0 4.0
0.100 5.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 7.0 32.0 4.0
0.100 0 0 30.0
5.53 50.0

5.78 50.0
6.49 50.0
6.24 50.0
6.01 50.0
6.34 50.0
7.00 50.0
0 0.000 0.000 0.000 0.000
0.0 0.0 0.0 0.0
0.20 50.0
0.50 50.0
0.52 50.0
0.53 50.0
0.55 50.0
0.58 50.0
0.59 50.0
0 4.00 1.00 4.00 10.00
50.0 15.0
0.0 0.0 0.085 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.135 30.0 30.0
0.0 0.0 0.100 30.0 30.0
0.0 0.0 0.090 30.0 30.0
0.0 0.0 0.085 30.0 30.0
0 0 0
45.0 0.70 100.0 200.0 200.0
1200.0 200.0 200.0 200.0 1200.0
0.0 0.0 0.0 0.0 0.0
240.00 30.0
400.00 30.0
400.00 30.0
400.00 30.0
300.00 30.0
270.00 30.0
240.00 30.0
1.600000 10.000000
0.100 0.333
20.000 0.333
10.000 0.333
10.000 0.333
10.000 0.333
1.000 0.333
100.000 0.333
0.750 0.333

0.750 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
0.000 0.333
1.00 1.00 1.00 1.00 1.00
0.30 0.30 0.50 0.02 0.50
0.20 0.20 0.20 0.20 0.20
1.0 1.0 1.0 1.0 1.0
9.0 1.0 6.0 0.060 0.200 0.060
1.0 1.0 1.0 1.0
9.00 9.00 2.0 0.0
10.0 10.0 10.0 50.0
0.020 200.0 1000.0 0.10
0.00 0.00 30.0 0